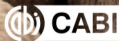




**THE
SLAUGHTER
OF
FARMED
ANIMALS**

PRACTICAL WAYS OF
ENHANCING ANIMAL WELFARE

Edited by **Temple Grandin** and **Michael Cockram**



The Slaughter of Farmed Animals

Practical Ways of Enhancing Animal Welfare

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Edited by

Temple Grandin

Department of Animal Science, Colorado State University, USA

and

Michael Cockram

*Sir James Dunn Animal Welfare Centre, Atlantic Veterinary College,
University of Prince Edward Island, Canada*



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CABI
Nosworthy Way
Wallingford
Oxfordshire OX10 8DE
UK

CABI
745 Atlantic Avenue
8th Floor
Boston, MA 02111
USA

Tel: +44 (0)1491 832111
Fax: +44 (0)1491 833508
E-mail: info@cabi.org
Website: www.cabi.org

Tel: +1 (617)682-9015
E-mail: cabi-nao@cabi.org

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Contributors

- Faith Baier**, Department of Dairy Science, University of Wisconsin, Madison, USA. Email: fbaier@wisc.edu
- Miki Ben-Dor**, Department of Archaeology and Ancient Near Eastern Cultures, Tel Aviv University (TAU), Tel Aviv, Israel. Email: bendor.michael@gmail.com
- Charlotte (Lotta) Berg**, Department of Animal Environment and Health, Swedish University of Agricultural Sciences, Skara, Sweden. Email: Lotta.berg@slu.se
- Michael Cockram**, Sir James Dunn Animal Welfare Centre, Dept. of Health Management, Atlantic Veterinary College, University of Prince Edward Island, Charlottetown, PEI, Canada. Email: mcockram@upei.ca
- Lily N. Edwards-Callaway**, Department of Animal Science, Colorado State University, Fort Collins, Colorado, USA. Email: lily.edwards-callaway@colostate.edu
- Temple Grandin**, Department of Animal Science, Colorado State University, Fort Collins, Colorado, USA. Email: cheryl.miller@colostate.edu
- Helen Kline**, JBS Swift, Tolleson, Arizona, USA. Email: Helen.Kline@jbssa.com
- Andy Lamey**, Department of Philosophy, University of California, San Diego, California, USA. Email: alamey@ucsd.edu
- Frédéric Leroy**, Industrial Microbiology and Food Biotechnology, Faculty of Sciences and Bioengineering Sciences, Vrije Universiteit Brussel, Brussels, Belgium. Email: Frederic.leroy@vub.be
- Frank Mitlochner**, Department of Animal Science, University of California-Davis, Davis, California, USA. Email: fmmitlochner@ucdavis.edu
- Mohan Raj**, Formerly Reader in Animal Welfare, Department of Clinical Veterinary Science, University of Bristol, UK. Email: abmraj1957@gmail.com
- Bernard Rollin**, Department of Philosophy, Colorado State University, Fort Collins, Colorado, USA. Email: Bernard.rollin@colostate.edu
- Peter Singer**, University Center for Human Values, Princeton University. Email: singerp@gmail.com
- Claudia Terlouw**, Clermont Auvergne University, INRAE, VetAgro Sup, UMR Herbivores, F-63122 Saint-Genès-Champanelle, France. Email: claudia.terlouw@inrae.fr
- Erika Voogd**, Voogd Consulting, 28 West 225 Trieste Lane, West Chicago, Illinois, USA. Email: evoogd@voogdconsulting.com
- Dennis Willson**, Department of Animal Science, Colorado State University, Fort Collins, Colorado, USA. Email: dennis.willson@colostate.edu

Preface

This book provides both practical information that can be used in commercial abattoirs and in-depth reviews of scientific research on animal welfare. The two editors, Temple Grandin and Michael Cockram, provide different perspectives. Dr Grandin provides practical applied information that can be immediately put to use. Dr Cockram's chapters contain extensive literature reviews on transport, legislation, the condition of livestock and poultry that arrive at the abattoir, and on-farm welfare problems that can be assessed at the slaughter plant. Dr Grandin has chapters on stunning methods for livestock and poultry, determining unconsciousness, design of stun boxes and lairages, handling of animals, methods to prevent bruises, and the effects of pre-slaughter handling on meat quality. Other topics that are covered are assessment of animal welfare in slaughter plants and non-stunned religious slaughter. For a true international perspective, additional invited authors from Belgium, France, Sweden and the UK provide important research information on the welfare of livestock and poultry during stunning and slaughter. There is a comprehensive chapter on determining whether or not an animal is conscious. Five short chapters at the end of the book discuss the ethics of eating meat. It is important for the readers to understand differing viewpoints. This book will be especially useful for animal welfare officers in meat plants, veterinarians, meat scientists, regulatory officials, abattoir managers and students interested in animal welfare.

1

Introduction to Livestock and Poultry Welfare at Slaughter

TEMPLE GRANDIN*

Department of Animal Science, Colorado State University, USA

Our book on animal welfare at slaughter is aimed at abattoir managers, welfare officers, government regulators and supervisors of retail food supply chains. Retailers are increasingly enforcing private standards for their suppliers. Guidance from this book will assist quality assurance personnel, veterinarians and managers who are responsible for maintaining good animal welfare. It will also be a valuable text for students interested in either animal welfare or meat science. There is a major emphasis on cattle, pigs, sheep and broiler chickens. Information will also be included on other mammals and poultry.

This book is a combination of both practical 'how to' chapters by Temple Grandin and more in-depth scientific review chapters by Michael Cockram and invited authors. The first and second editors provide different perspectives. I have worked with the meat industry for over 40 years on equipment design, development of welfare auditing programmes and hands-on handling of livestock (Grandin, 2003, 2014, 2016). My chapters will cover methods to achieve the best possible welfare under commercial conditions. All stunning methods have welfare advantages and disadvantages. Scientific research on some methods, such as captive bolt and electrical stunning, has identified how these methods can be applied in practice to reduce the risk of welfare concerns. There are differences between the various types of controlled atmosphere (gaseous) stunning methods. The animal's reaction is highly variable depending on the type of gas, application method and species of animal (pigs versus poultry). The controversial subject of religious slaughter without stunning will also be covered (Chapter 11). Commercial application of methods of stunning

that some religious authorities will accept will also be discussed. In this introductory chapter, there is an overview of the topics that will be covered.

Michael Cockram has a veterinary and academic background in animal welfare. He has published research on the transport, lairage and handling of livestock and poultry, and other animal welfare issues. Much of this work has been undertaken within commercial slaughter plants. He has worked with several industry groups to apply the results of scientific research to commercial situations and has participated in the development of several animal welfare codes of practice. He presents the scientific evidence of welfare issues at slaughter in Chapter 2.

My Chapter 3 covers animal welfare tradeoffs when choosing between different technologies for commercial use. There are also chapters on the commercial application of stunning methods on cattle, pigs, sheep and poultry. Claudia Terlouw from the French National Institute for Agricultural Research covers the latest research studies for determining when an animal is unconscious (Chapter 14). Lotta Berg from the Swedish University of Animal Welfare Science covers the scientific research on poultry welfare during stunning (Chapter 7). Other issues covered by invited authors are prevention of bruising, by Lily Edwards-Callaway from Colorado State University (Chapter 5), and a series of shorter essays on the ethical arguments both for and against using animals for food (Chapter 18). Pre-slaughter handling of both livestock and poultry will be covered in detail. Practical guidance is provided on the design of restraint devices, lairages and races. There is a 'how to' chapter on behavioural principles of handling cattle, pigs and sheep (Chapter 6). Cockram has two additional

* Email: cheryl.miller@colostate.edu

chapters which cover problems that originate either on the farm or during transport and legislative issues (Chapters 4 and 17).

A Major Question About Welfare at Slaughter

A common question that people concerned about animal welfare often ask is: do animals know they are going to be slaughtered? When I first started my career in the early 1970s, I had to answer this question. To find out, I repeatedly travelled back and forth between a large beef slaughter plant and a local feedlot where people were vaccinating cattle. I was surprised to observe that the cattle behaved the same way in both the vaccinating race and the race that led to a captive bolt stunner. If they knew they were going to be slaughtered, their behaviour should have been much more agitated at the slaughterhouse. Research studies have shown that the levels of cortisol (stress hormone) have a similar range at both the ranch and the abattoir (Mitchell *et al.*, 1988; Grandin, 1997, 2014; Gruber *et al.*, 2010). In both places, the range of cortisol levels varied from very low to extremely high. The most important finding was that the range of cortisol values was similar in both places. Stress during handling can be lowered by training employees, better management supervision and simple modifications of equipment that are described in this book.

A common mistake made by people who want to improve animal welfare is to believe that buying the newest fancy equipment will fix all the animal welfare problems. I made this mistake early in my career when I thought that I could design a system that could replace management. Well-designed and engineered equipment is important, but it does not replace management and training of employees. Engineering and good equipment design can fix about half of the animal welfare problems, but the other half will require managers who care about animal welfare. One study showed that a major cause of poor stunning methods that failed to render cattle instantly unconscious was poor maintenance of the stunning equipment (Grandin, 2002). Poor maintenance is a management problem and not an equipment problem.

Simple Ways to Improve Existing Equipment

Maintaining an acceptable level of animal welfare is possible in abattoirs with basic modest equipment.

In many existing facilities, repairs and maintenance are often all that is required. There are many places where the best stunning equipment was purchased but the managers fail to maintain it. Ease of animal movement through a race can often be improved with easy fixes. Sometimes all that is required is to install a solid barrier to prevent approaching animals from seeing people or moving equipment ahead of them. Simple modifications, such as installing non-slip flooring in a stun box or changing lighting, will help keep pigs or cattle calmer. Illumination of a race entrance may make it possible to greatly reduce or eliminate electric goad (prod) use (Grandin, 2001). Pigs and cattle often refuse to enter dark places. Managers, veterinarians and plant employees will find lots of practical tips in this book.

Numerical Animal-based Measures of Welfare

I have worked hands-on in meat plants for over 40 years. During my career, I have been in over 300 beef, pork, lamb and poultry abattoirs in the USA, Canada, Mexico, South America, Europe, China, Australia and New Zealand. I have observed both the very best and the worst operations. I have designed stockyards (lairages), races and restrainer systems in abattoirs all around the world. At this late stage in my career, I am often asked what I am most proud of. During the 1970s, 1980s and early 1990s, I became increasingly frustrated that some of my clients did a poor job of operating facilities I had designed. What kept me motivated was that there were a few managers who did things right and supervised their employees.

In 1997, I developed a numerical scoring system, which used outcome indicators of poor animal welfare (Grandin, 1998). It became the basis of the US meat industry private standard. There are five simple outcome measures. To pass an audit, a plant had to achieve a good score on all five indicators. This system is discussed in detail in the book. The indicators are: (i) percentage of cattle, pigs or sheep effectively stunned with one application of the stunner; (ii) percentage rendered unconscious when hung on the bleed rail (must be 100%); (iii) percentage of cattle or pigs vocalizing (moo, bellow or squeal) during handling and restraint; (iv) percentage that fall down during handling; and (v) percentage moved with an electric prod. The advantage of numerical scoring is that it makes it easy to

determine if handling and stunning practices are improving or becoming worse. There are also six acts of abuse which would be an immediate audit failure.

The next step in my career was to teach large retail meat buyers how to use the scoring system. In 1999 and 2000, after I started working with retail buyers, I observed more improvements in welfare than I had seen in my previous 25-year career. When the abattoirs were required to perform to an objective standard, they really improved (Grandin, 2005). It worked because it was objective and simple. Most of the abattoirs were able to pass the audits by improving employee training, better management supervision, increased stunner maintenance and simple modifications of facilities. This book can be used to teach people how to use behaviour principles to achieve low-stress livestock handling. People who work with animals need to be shown that handling will be more efficient if forceful methods are eliminated.

Did My Work Achieve Good Animal Welfare?

By using a combination of repairs, good management and simple modifications, I was able to make handling at a large slaughter plant less stressful than handling on many ranches. The average vocalization scores of cattle were lower at the abattoir (Grandin, 2001) than cattle handling on some ranches (Simon *et al.*, 2016). In cattle, vocalization during handling is related to physiological measures of stress (Dunn, 1990; Hemsworth *et al.*, 2011). For example, reducing the pressure applied by a head stanchion (head bail) reduced vocalization from 23% of the cattle down to 0%. Stress and pain have been greatly reduced compared with the bad old days of the 1970s, 1980s and 1990s. Many students and other people who are entering the industry today have never seen the awful conditions that existed during the first half of my career.

Welfare Issues that Originate at the Farm

I am becoming increasingly concerned about welfare issues that originate on the farm. Recently I was standing by the unloading ramp of a large plant that processed fed cattle. Many of the cattle were stiff and lame when they were unloaded off the truck. Fifteen years ago, problems with lame grain-fed beef were rare. The increased problems with lameness

in fed cattle are due to several factors that jointly increase stress on the animal's biology. They are heavier weights at a younger age, a genetic component, a lack of roughage in the diet and overuse of beta agonist growth promoters. At another abattoir, one of my colleagues has become increasingly disgusted at the condition of old dairy cows. They are allowed to deteriorate to a very poor condition before they are sold for slaughter. Most of these farm-related welfare problems come from a segment of poor producers. Over the years, many producers have greatly improved conditions on their farms. Slaughterhouses are the easiest part of the system to find remedies to improve animal welfare. The biggest challenge in animal welfare is to make sure that the animals on the farms had a life worth living.

The next step that can be taken to improve animal welfare is to measure welfare indicators of poor farm conditions at the abattoir. For livestock, some of the animal-based indicators that can be used are body condition score, lameness, swollen knee joints, hide cleanliness, bruises, death losses during transit, liver abscesses, lung lesions and infestations of lice. Poultry can also be assessed for conditions caused by poor housing. Some of the animal-based indicators for poultry are breast blisters, hock burn and foot pad lesions. The percentage of fractured wings can be used to audit poultry handling during catching.

In conclusion, I would like to add that pain, fear and discomfort can be reduced by following the best practices in our book.

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2

Welfare Issues at Slaughter

MICHAEL COCKRAM*

*Sir James Dunn Animal Welfare Centre, Atlantic Veterinary College,
University of Prince Edward Island, Canada*

Summary

This chapter discusses animal welfare in the context of slaughter and reviews the types of welfare issues that some animals can experience before and during slaughter. It shows how animal feelings such as pain, distress, fear, hunger, thirst, fatigue and discomfort can be affected by the procedures associated with slaughter and how responses to these states can be recognized. It concludes with a discussion on methods of assessing animal welfare at slaughter.

Learning Objectives

- Ethical approaches to welfare at slaughter.
- Criteria to assess slaughter methods.
- Potential causes of fear and stress.
- Understand possible causes of fear and stress.
- Learn physiological measures of stress.
- Animal welfare assessment methods.

Introduction

In introducing the broad concepts of animal welfare and humane slaughter, it is not the intention to imply that all of the potential welfare issues discussed will routinely occur during the slaughter of animals. The intention is to use the published literature to identify risks to animal welfare during slaughter, explain the nature of these potential welfare issues and show how to recognize them. Subsequent chapters will discuss how attention to detail, supervision and regulation (both self-regulation and external party regulation) can mitigate these risks to animal welfare.

Welfare issues can occur if animals arrive for slaughter already experiencing pain and discomfort,

if they experience problems during handling, lairage and restraint for stunning, and if stunning is ineffective. To avoid the risk of welfare issues during slaughter requires considerable attention to detail and conformity with best-practice guidelines. Close supervision is required to avoid a tendency to reduce the level of care provided in the misguided belief that optimal care is not required, due to the imminence of slaughter (Cortesi, 1994).

Grandin (2014) identified three categories of welfare issues that can arise during slaughter. One was when abuse, cruelty or neglect occurred due to the action of humans who were not adequately supervised. The second occurred where the operating procedures were appropriate, but there was a defect in the procedures undertaken that could be remedied by corrective action. The third category occurred where there were inherent welfare issues with the systems and procedures used for slaughter.

Humane Slaughter

Slaughter is the killing of animals for food, and humane slaughter is slaughter that shows sympathy with and consideration for the animals; it demonstrates compassion and is designed or calculated to inflict minimal pain (Oxford English Dictionary, 2018). It is, therefore, a combination of ethical treatment and a technical consideration of how to minimize any pain associated with slaughter. The term humane slaughter is used most often to refer to effective stunning, i.e. stunning that causes immediate loss of consciousness that persists until the animal is killed by exsanguination (bleeding or 'sticking') or by cardiac arrest. In developed countries, methods used for stunning and slaughtering

* Email: mcockram@upei.ca

animals have improved due to technical innovations and greater proficiency in their application. In developing countries, welfare standards at slaughter can be diverse, with a range of slaughter methods used that may be applied within domestic and communal settings rather than in specialized slaughter facilities (Lokuruka, 2016; Omotosho *et al.*, 2016; Qekwana *et al.*, 2017). Several examples of welfare issues at slaughter are provided from countries that have a different regulatory and commercial environment to those in, for example, North America, Europe and Australasia.

If animals are immediately killed or immediately stunned and rendered unconscious (i.e. a state of unawareness in which there is temporary or permanent disruption to brain function) and insensible (i.e. the animal is not able to experience pain and other mental states) until death occurs (Verhoeven *et al.*, 2015), they will not experience pain or distress during the slaughtering procedure and the process is considered to be humane. Failure to respond to the application of a mildly painful stimulus that would be expected to be painful to a conscious animal is used as an indicator of loss of responsiveness after effective stunning (McKinstry and Anil, 2004; Hindle *et al.*, 2010; Terlouw *et al.*, 2016).

Ethical Approaches to Welfare at Slaughter

Slaughter is a topic where there are divergent ethical perspectives and some of these are absolute and prevent consensus. Sympathy with and compassion for animals has led some people to consider that the slaughter of animals or some types of animals is unethical. Although science is not able to answer ethical questions such as what is 'appropriate' (Rollin, 2015), animal welfare issues that form part of social debate can be investigated using scientific principles. This research attempts to understand how animals perceive their situation and whether practices can be modified to reduce the risk of suffering. If an animal is not subjected to pre-slaughter pain, fear or stress, is stunned instantaneously and does not recover consciousness before death, death itself is not a welfare issue (Broom, 1998). The aim of this chapter is not to challenge the consumption of meat or to persuade people away from meat eating, but to discuss the welfare issues that can arise during the slaughter of animals for food. The majority view is that it is ethically acceptable to

slaughter animals, but most would impose the requirement to slaughter animals in the most humane manner consistent with the production of sufficient quantities of economical meat. Therefore, this chapter will not consider the death of an animal to be a welfare issue but only consider how it dies and the treatment of the animal during the pre-slaughter stages.

Ambivalence about livestock

Many people are ambivalent about the slaughter of animals for food and prefer not to consider or find it challenging to discuss the process of killing animals for their food (Abrams *et al.*, 2015; Bray *et al.*, 2016). This has led to the use of words that avoid reference to slaughter. Examples are the use of the word abattoir or processing plant rather than slaughterhouse or slaughter plant, and harvesting rather than slaughter, as ways of avoiding a direct description of slaughter or killing. The general public tends not to have a great deal of knowledge or experience of animal production and slaughter and therefore their views on many welfare issues may not be fully informed (Food Chain Evaluation Consortium, 2015; Cornish *et al.*, 2016). Most consumers prefer to leave it to others such as regulators, the meat industry, food retailers and lobby groups to ensure that their meat is from animals slaughtered humanely. Therefore, political and commercial considerations have led to a range of animal welfare legislation, guidelines (Leary *et al.*, 2016; OIE, 2016; European Commission, 2017; Grandin, 2017a), standards (Main *et al.*, 2014; Lundmark *et al.*, 2018) and audit procedures (Grandin, 2010) that place a responsibility on the slaughter plant for the welfare of the animals.

Meat Industry Practices and Animal Welfare

In developed countries, slaughterhouses are a centralized facility that can efficiently slaughter large numbers of animals in a regulated and industrialized environment and they avoid the use of numerous small dispersed locations within populated areas (Fitzgerald, 2010). However, one consequence is that this has separated contact between the public and the act of slaughter (Leroy and Praet, 2017). For economic reasons slaughterhouses have become large, specialized in specific types of animals and are fewer in number (MacDonald, 2003; Muth

et al., 2007). The risks to animal welfare are considered by some to be lower in small-scale slaughter facilities than in large ones (Hultgren *et al.*, 2016) and the levels of noise and stress experienced by the animals are thought to be greater in plants with a high throughput (Warriss *et al.*, 1994). In an attempt to avoid welfare risks (e.g. injury and stress) associated with the transportation of animals to slaughter in distant large plants, the use of mobile abattoirs that can move between farms has been investigated (Carlsson *et al.*, 2007). In one study, the signs of stress in sheep (serum cortisol concentration at exsanguination) were found to be lower after captive bolt stunning at a mobile on-farm abattoir than after transport, lairage, regrouping and handling followed by electrical stunning at a conventional abattoir (Eriksen *et al.*, 2013). However, mobile abattoirs have several economic and technical challenges compared with traditional slaughter plants (Hoeksma *et al.*, 2017) and represent a very small part of the industry.

Consider the entire food production chain

The slaughter of animals needs to be considered within the context of the entire food production chain: rearing on the farm, transport to slaughter, handling, lairage and slaughter, followed by processing, storage and delivery of the products to food manufacturers, distributors and retailers. Integrated companies that are involved in all or several stages in the food chain and some end users such as fast-food restaurants and large supermarkets that source their meat directly from specific slaughter plants aim to provide assurance on the quality and provenance of the meat and conformity with the standards of animal welfare that are required by the public and consumers (Harvey and Hubbard, 2013). Many companies that operate slaughter facilities in developed countries (but not necessarily those in some developing countries, e.g. see Frimpong *et al.*, 2014) give priority to animal welfare, but it is not the only consideration for the slaughter industry. The management of slaughter plants can be affected by a number of priorities and challenges that affect their viability (Charlebois and Summan, 2014). They need to manage their operations in a manner that is as economical as possible; delivers a product in sufficient quantity and quality to meet market demands; conforms to requirements for food safety, animal health, human health and safety; provides a service for the agricultural

community; satisfies environmental concerns and is sustainable; and complies with industry or retail standards and legal regulations (Seng and Laporte, 2005).

Criteria to assess slaughter methods

There are several situations where animals might not be slaughtered using a method that poses the lowest risk to animal welfare. When developing guidelines on appropriate methods for humane slaughter, the American Veterinary Medical Association (Leary *et al.*, 2016) used some criteria that related to broader practical issues and not just those solely confined to animal welfare issues. They used the following criteria to assess methods used for slaughter:

- ability to induce loss of consciousness followed by death with a minimum of pain or distress;
- time required to induce loss of consciousness and the behaviour of the animal during that time, especially for religious slaughter;
- reliability and irreversibility of the methods resulting in death of the animal;
- safety of personnel;
- compatibility with intended animal use and purpose (i.e. meat consumption);
- potential psychological or emotional impacts on personnel;
- ability to maintain equipment in proper working order; and
- legal and religious requirements.

Market or societal demands

An example of the choice of a slaughter method that is not based on welfare criteria is where there is a market or societal demand for slaughter in conformity with religious practices, for example kosher or halal slaughter without adequate stunning. Another example is where electrical stunning is conducted with a low current to minimize the risk of product quality defects such as haemorrhages or bone fragments, but this can in some cases cause paralysis without insensibility to pain, whereas the use of a higher current would reduce the risk of an ineffective stun (Gregory and Wilkins, 1989; Raj, 1998). A similar situation applies to the use of head-back electrical stunning where there are welfare advantages compared with head-only stunning in that the animal is killed by cardiac arrest and the stun–stick interval is not critical (Raj, 1998).

However, this method might not be used due to the increased risk of bone fractures and meat quality defects (Gregory and Grandin, 1998). That said, there are often synergies between improved welfare and economic efficiency at slaughter (Støier *et al.*, 2016). It is easier and safer to handle animals that are calm compared with those that are stressed, fearful or in pain. Poor welfare conditions can often result in poor meat quality, such as pale soft exudative (PSE) and dark firm dry (DFD) meat, and damage (e.g. bruising) to meat, carcasses and hides/skins (Wigham *et al.*, 2018). As stress during pre-slaughter procedures (Hambrecht *et al.*, 2004) and the act of stunning can affect meat quality, considerable attention is given to the reduction of stress and this can influence the choice of handling and slaughter systems adopted.

Food Safety Risks and Animal Welfare

Food safety concerns can also influence the choice of stunning and killing method. Food safety risks preclude the use of chemicals that would remain in the body after death. Therefore, if the meat is used for human consumption, the chemicals that are available for euthanasia that cause sedation and suppression of heart and brain function cannot be used. There is a similar problem with the use of drugs to reduce pre-slaughter stress (Mota-Rojas *et al.*, 2011). Although pithing (the insertion and movement of a rod through the hole in the head made by the captive bolt) is an effective way of destroying brain and spinal cord tissue, thereby reducing muscle movements (clonic activity) and killing an animal after stunning, its use is now restricted to euthanasia rather than slaughter for human consumption (Appelt and Sperry, 2007). This is due to the risk of the spread of transmissible spongiform encephalopathies from cattle and sheep by the dissemination of central nervous system tissue (Anil *et al.*, 2002). Biosecurity and food safety requirements for ease of cleaning and disinfection require the extensive use of metal equipment and sometimes restricted use of bedding in the lairage (Small *et al.*, 2003). However, the use of metal fittings can be noisy and a source of fear to the animals (Waynert *et al.*, 1999). In some countries, in an attempt to reduce the surface contamination of animals with faeces and mud, and thereby reduce the risk of bacterial contamination of the meat, some sheep have been washed on arrival in the lairage using either a bath/dip or spray (Biss and

Hathaway, 1996). However, this practice is stressful for sheep (Hargreaves and Hutson, 1990) and is not effective in reducing food safety risks. Emphasis is now given to ensuring that only clean animals arrive for slaughter.

Animal Welfare and Emotions/ Feelings in Animals

A central aspect of the study of animal welfare is attempting to understand the subjective mental feelings, experiences and emotions of animals (Duncan, 2005). Animals used for slaughter likely experience a range of feelings or subjective emotional experiences during pre-slaughter procedures and the act of slaughter (Terlouw *et al.*, 2008). Most regulations on slaughter require that animals are not subjected to avoidable pain, distress or suffering during slaughter and related operations. Increased knowledge and understanding of the underlying biology of domesticated animals together with advances in neuroscience, behaviour and psychology have formed the basis for scientific approaches to animal welfare issues (Broom, 2011). This scientific approach to animal welfare, i.e. one that follows a systematic methodology, based on evidence to pursue and apply knowledge and understand the natural and social world (Science Council, 2009), can provide valuable evidence to assist society and relevant stakeholders in making ethical decisions on animal welfare issues (Duncan, 2005).

Mental and affective states

Emotions and other feelings (such as hunger and thirst) that can be experienced as mental states are collectively described as affective states (Fraser, 2008) and are thought to have evolved in animals as a way of providing a more flexible way of meeting their basic needs than just relying on simple nervous reflexes (Duncan, 2005). Stimuli that affect an animal's allostasis (i.e. the balance in physiological systems that is adjusted according to the animal's situation) are thought to be responsible for creating an affective state. An affective state is characterized by its valence (i.e. whether it is a positive or negative feeling) and the degree of arousal or calming that is induced to enable the animal to respond to the information received concerning potential risks (Barrett *et al.*, 2007; Bliss-Moreau, 2017). Suffering occurs when an animal

experiences one or more negative feelings such as pain, fear, hunger, thirst or discomfort for a prolonged period. The severity of any suffering is related to the duration and intensity of the negative state (Dawkins, 1990; Broom, 2011; Fraser, 2012).

Mental states in animals cannot be directly observed and measured (Fraser, 2009) and there is inconsistency both in psychological definitions and in concepts (de Vere and Kuczaj, 2016). Therefore, it is considered easier to attempt to assess welfare by making empirical measurements of health, biological function and the ability of animals to meet basic physiological needs. However, the ethical concerns about the welfare of animals, such as the risk of suffering during slaughter, relate to the capacity of domesticated animals to experience pain and other emotions and the circumstances that can induce these negative affective states. Therefore, the evidence for the main emotions and feelings that animals likely experience at a slaughter plant will be considered. The evidence to support the presence of emotions in animals is based on inductive reasoning, i.e. the balance of evidence, rather than on traditional empirical 'objective' science that can produce 'hard' evidence. The acknowledgement that animals that are killed for human consumption might or are likely to have the capacity to experience feelings such as pain, fear and stress can be challenging, especially for those involved in the meat industry. There can also be a tendency for those involved in food animal production to be more sceptical of the research that supports mental feelings in domestic animals than that of some other groups (Bastian *et al.*, 2012) who adopt a 'precautionary principle' approach in that they consider that it is preferable to assume that animals have the capacity to suffer. Although a scientific approach to animal welfare is an evidence-based approach rather than one that considers animal welfare issues solely from a moral or anthropomorphic perspective (the empathetic attribution of human characteristics including thoughts and emotions to domestic animals), it is nevertheless founded on a 'belief that animals have conscious feelings and are capable of experiencing pain and emotions' (Dawkins, 2017).

Similarities between animal and human neurology

The neurological basis of emotions, i.e. the type of activity in nerve cells in the brain of humans and

other animals that produce emotions and other feelings, is not known (Dawkins, 2006). However, there are sufficient similarities between humans and domesticated animals in their brain structure and function, and in their behaviour and physiology, to suggest that animals likely experience affective states (Hemsworth *et al.*, 2015). When animals are in circumstances where humans would have an emotional experience, many of the responses made by domesticated animals are similar to those shown by humans when they report that they are experiencing a specific mental state. As affective states cannot be measured directly in animals, physiological and behavioural responses are measured that are thought to be related to these experiences (Hemsworth *et al.*, 2015). These responses can include neurophysiological and other physiological measurements, facial expressions and overt behaviours (Adolphs and Andler, 2018). In general, non-human mammals are motivated to seek similar emotional rewards and to avoid similar negative emotional events to those of humans. Human emotional feelings are dependent on similar subcortical brain systems that exist in both humans and many non-human animals (Panksepp, 2005). For example, in humans and other animals, the region of the brain known as the amygdala is considered to be involved in emotional experiences, such as fear, and in subsequent behavioural responses to fear, such as immobility (Cardinal *et al.*, 2002; Anderson and Adolphs, 2014). Electrical activation of these brain systems results in similar types of emotional expressions in humans and many non-human animals (Panksepp, 2005). The areas of the brain that are activated when humans experience a feeling such as thirst are also present in mammals and birds (Dawkins, 2006). There is pharmacological evidence that many drugs that control pain or fear/anxiety in humans appear to have similar effects in non-human animals (Hughes *et al.*, 1977). For example, lame broilers but not those with a normal gait have been shown to select food containing a non-steroidal anti-inflammatory drug over food without the drug and then show improved gait (Danbury *et al.*, 2000). Pigs given an anxiolytic will show reduced fear responses to novelty (Andersen *et al.*, 2000b; Dalmau *et al.*, 2009a).

Although domesticated animals likely have subjective feelings, they may not necessarily be similar to those experienced by humans (Dawkins, 2008). However, to act on suffering, it is not necessary to know exactly what an animal is feeling, only that

there is evidence that the animal is likely experiencing a negative mental state, the severity of the suffering and its duration (Duncan, 2005). Examples of the factors that can cause negative affective states in animals at a slaughter plant are described below and signs that will assist in their recognition are discussed. It must be recognized that there are no consistent, discrete and specific markers of emotions, i.e. each emotion does not produce a distinct set of reproducible behavioural and physiological responses (Bliss-Moreau, 2017). Several emotions, e.g. pain and fear, can result in general arousal with increased activity, attention to surroundings and autonomic nervous system activity (fight or flight) or a passive response consisting of decreased activity and immobility. Events likely to induce different affective states can be associated with the same types of physiological responses. For example, increases in plasma cortisol concentrations and heart rate can be associated with negative emotions such as pain, fear and distress, as well as neutral events such as physical activity or positive ones such as feeding (Ralph and Tilbrook, 2016). Non-specific indicators of welfare can still be useful if they act as a warning of a potential issue that requires investigation and possibly corrective action.

Pain

Pain is ‘an unpleasant sensory and emotional experience associated with actual or potential tissue damage’ (International Association for the Study of Pain, 2017). Examples of potential causes of pain during pre-slaughter and slaughter procedures are shown in Table 2.1. Pain can potentially occur from injuries present on arrival, sustained in the lairage or during handling; from electricity and mechanical injury if stunning is not conducted appropriately; from starting to process an animal while it is still sensible to pain; and from undertaking exsanguination before stunning.

The consensus interpretation of the available evidence is that all mammals and birds are capable of experiencing pain (Sneddon *et al.*, 2014). Bateson (1991) summarized the following similarities between humans and domesticated animals that suggest that domesticated animals can also experience pain. They both possess nervous system components that include receptors sensitive to noxious stimuli, brain structures equivalent to the human cerebral cortex, connections between these receptors and higher brain structures, and receptors for

opioid substances in the brain. Analgesics modify responses to noxious stimuli and are selected by animals when they have damage likely to be associated with pain. In response to noxious stimuli, they attempt to avoid them or minimize the damage that they cause; these responses persist and animals learn how to associate neutral events with noxious stimuli. As there are differences in species-specific behaviour and neuroanatomy, this argument by analogy does not provide conclusive evidence. For example, it is also possible that some of the responses shown by animals are in response to nociception (i.e. a response to potentially damaging stimuli that does not require a subjective experience) rather than to pain (Sneddon, 2018). Body movements in response to nociception can be due to spinally-mediated reflex activity that does not require brain activity. The brain, and in particular the cerebral cortex and associated subcortical structures, must be functional for pain to be perceived. Therefore, if stunning is effective and the cerebral cortex is not functional because of physical disruption, hypoxia, an epileptic seizure or neuronal depression, pain cannot be experienced (Leary *et al.*, 2016).

Absence of pain with effective stunning

Examples of research that supports the absence of pain with effective stunning are as follows.

- The disruption to brain activity that follows effective captive bolt stunning causes almost instantaneous loss of awareness to pain (Johnson *et al.*, 2012).
- If an electric current is passed across the brain in a manner that induces epileptiform brain activity and causes loss of consciousness in less than 1 s, this is unlikely to be a painful experience (Berg and Raj, 2015). However, if an electric current is applied to the body before an animal loses consciousness, the animal can experience discomfort directly from the electricity, cardiac and skeletal muscle pain, and pain associated with heart failure (Gregory and Grandin, 1998).
- Leach *et al.* (1980) showed that sheep conditioned to expect electrical stunning by receiving prior exposure to a light source did not show an increase in heart rate when shown the light without electrical stunning. As no autonomic nervous system response was activated by the light, the absence of an increase in heart

Table 2.1. Examples of potential causes of pain in animals during pre-slaughter and slaughter procedures.

Examples of potential causes of pain	Reference
<i>Injury, disease or neglected conditions present on arrival</i>	
<ul style="list-style-type: none"> pre-existing lesion, e.g. lameness that was present on the farm before loading severely debilitated or weak animals lactating dairy cows that have not been dried up injury sustained during handling or transport 	Flower and Weary (2009); Gentle (2011); Dalmau <i>et al.</i> (2016)
<i>Injuries that occur during unloading, movement and handling</i>	
<ul style="list-style-type: none"> sharp protrusions causing skin lacerations or bruising, slippery floors resulting in slips and falls physical force used by a handler on an animal either directly or with a tool twisting an animal's tail 	Langkabel <i>et al.</i> (2015) Grandin (1997) Hultgren <i>et al.</i> (2014)
<ul style="list-style-type: none"> lifting or dragging/pulling an animal by its head, horns, feet, tail or fleece 	Pajor <i>et al.</i> (2000); Frimpong <i>et al.</i> (2014); Hultgren <i>et al.</i> (2014); Romero <i>et al.</i> (2017) Jarvis <i>et al.</i> (1994); Frimpong <i>et al.</i> (2014)
<i>Injuries in lairage</i>	
<ul style="list-style-type: none"> injuries caused by aggressive interactions between animals (especially in mixed social groups) animals slipping, falling and mounting during unloading or within the lairage 	Warriss and Brown (1985); Warriss <i>et al.</i> (1998); Gispert <i>et al.</i> (2000); Faucitano (2001) Kenny and Tarrant (1988); Miranda-de la Lama <i>et al.</i> (2012); Dalmau <i>et al.</i> (2016)
<i>Use of electric goad/prod</i>	
<ul style="list-style-type: none"> especially on sensitive parts of the body^a 	Bourguet <i>et al.</i> (2011a); Hemsworth <i>et al.</i> (2011); Miranda-de la Lama <i>et al.</i> (2012); Hultgren <i>et al.</i> (2014); Romero <i>et al.</i> (2017)
<i>Shackling before stunning</i>	
<ul style="list-style-type: none"> shackling of poultry before electrical stunning 	Sparrey and Kettlewell (1994); Gentle and Tilston (2000)
<i>Stunning</i>	
<ul style="list-style-type: none"> electrical shocks to poultry before stunning in water bath pigs or sheep in contact with another animal while it is electrically stunned or in contact with electricity from electrodes that are not placed appropriately on the head ineffective stunning not causing instantaneous unconsciousness or recovery of consciousness causing pain either directly from the stunning method or by susceptibility to painful stimuli from other slaughter procedures, e.g. exsanguination failure to apply sufficient current across the brain to cause insensibility before current is applied across the heart thereby inducing ventricular fibrillation in a conscious animal animals recovering from head-only electrical stunning due to a delay in exsanguination thereby becoming susceptible to painful stimuli animals that have not been effectively stunned and killed by exsanguination undergoing dressing (skin removal and cutting) immersion of poultry and pigs in hot water when they enter a scalding tank conscious after ineffective electrical stunning and/or ineffective exsanguination 	Gregory and Grandin (1998); Raj (1998); Rao <i>et al.</i> (2013); Berg and Raj (2015) Gregory and Wotton (1984); Grandin (2000) Velarde <i>et al.</i> (2000); Hindle <i>et al.</i> (2010); Miranda-de la Lama <i>et al.</i> (2012); Zivotofsky and Strous (2012); Gallo and Huertas (2015) Raj (1998) McKinstry and Anil (2004) Ahsan <i>et al.</i> (2014) Griffiths (1985); EFSA (2013); Parotat <i>et al.</i> (2016)
<i>Cutting neck tissues for exsanguination without prior stunning</i>	
<ul style="list-style-type: none"> pain from cutting tissues for exsanguination, especially when not undertaken with a sharp knife in one quick action 	Barnett <i>et al.</i> (2007); Gibson <i>et al.</i> (2009a,b); Bourguet <i>et al.</i> (2011a); Johnson <i>et al.</i> (2012); Johnson <i>et al.</i> (2015)

^aUse of electric goads/prods does not always cause a significant increase in plasma cortisol concentration or vocalizations (Probst *et al.*, 2014), but their use has been associated with vocalization and other physiological responses (Grandin, 2001; Warner *et al.*, 2007; Dupjan *et al.* 2008).

rate suggests that the sheep did not associate the light with a subsequent painful or fearful stimulus.

- Martin *et al.* (2016) investigated whether an analgesic reduced behavioural signs of pain/distress when broilers were exposed to low atmospheric pressure stunning. Although the results were not definitive, the behavioural responses suggested that the birds did not experience pain during the stunning procedure, for example from the expansion of trapped air in body cavities.

Pain assessment

Pain can be assessed by observing the behaviour and physiology of an animal. However, the behavioural signs that typically indicate pain and the associated changes in heart rate and respiratory rate are not specific to pain (National Research Council, 2009). Table 2.2 shows examples of common behavioural signs of pain, but there is considerable species variation, and individual variation within species, and many of the signs will depend on the type and severity of the pain.

Fear and Stress

Stress and distress

Before slaughter, animals are exposed to multiple potential stressors and each stage leading up to slaughter, including feed withdrawal, social mixing, handling, transport, lairage and slaughter, can be stressful (Table 2.3) (Terlouw *et al.*, 2008). The term stress describes the adaptive responses of an animal to environmental stimuli (stressors) that threaten its internal equilibrium (homeostasis/allotaxis) (Ramos and Mormede, 1998; Mormède *et al.*, 2007). The term distress has many definitions, but in this context, it will be differentiated from stress by using it to describe an aversive, negative emotional state that occurs when adaptive responses fail to return the body to homeostasis (Sanford *et al.*, 1986; National Research Council, 2009).

If environmental stimuli are perceived and evaluated as a stressor, a range of neuroendocrine, metabolic and behavioural changes occur in an attempt to respond to the challenges presented (Veissier and Boissy, 2007). No single biological measurement adequately characterizes a stressful response and no single stress response is present in all stressful

Table 2.2. Examples of behavioral signs of pain (adapted from National Research Council, 2009).

Sign	Description
Guarding	The animal alters its posture to avoid moving or causing contact to a body part, or to avoid the handling of that body area.
Abnormal appearance	Different species show different changes in their external appearance, but obvious lack of grooming, changed posture and a changed profile of the body are all observable signs. In species capable of some degree of facial expression, the normal expression may be altered.
Altered behaviour ^{a,b}	Behaviour may be depressed; animals may remain immobile, or be reluctant to stand or move even when disturbed. They may also exhibit restlessness (e.g. lying down and getting up, shifting weight, circling or pacing) or disturbed sleeping patterns. Large animal species may grunt, grind their teeth, flag their tail, stomp or curl their lips (especially sheep and goats). Animals in pain may also show altered social interactions with others in their group.
Vocalization	An animal may vocalize when approached or handled, or when a specific body area is touched or palpated. It may also vocalize when moving to avoid being handled.
Mutilation	Animals may lick, bite, scratch, shake or rub a painful area.
Sweating	In species that sweat (horses), excessive sweating is often associated with some types of pain (e.g. colic).
Inappetence	Animals in pain frequently stop eating and drinking, or markedly reduce their intake, resulting in rapid weight loss.

^aAnimals in severe pain can have rapid and shallow respiration. On handling, they may react violently or adopt a rigid posture to immobilize the painful region. Localized pain may be associated with persistent licking or kicking at the offending area and, when the pain is severe, bellowing.

^bBirds in pain show escape reactions, vocalization and excessive movement. Head movements increase in extent and frequency. There may also be an increase in heart and respiratory rates. Birds in chronic pain may exhibit a passive immobility characterized by a crouched posture with closed or partially closed eyes and head drawn toward the body. They may also become inappetent and inactive with a drooping appearance, holding their wings flat against the body and their neck retracted. When a bird is handled, its escape reaction may be replaced by immobility.

Table 2.3. Examples of potential causes of fear and stress in animals during pre-slaughter and slaughter procedures.

Examples of potential causes of fear and stress	Reference
<i>Handling and lairage</i>	
<ul style="list-style-type: none"> novel stimuli 	Mormede and Dantzer (1978); Veissier and Le Neindre (1988); Keer-Keer <i>et al.</i> (1996); Grandin (2013)
<ul style="list-style-type: none"> unpredictable stimuli such as noise from slamming gates or shouting by handler or exposure to loud noise 	Waynert <i>et al.</i> (1999); Campo <i>et al.</i> (2005); Hambrecht <i>et al.</i> (2005); Terlouw and Rybarczyk (2008); Chloupek <i>et al.</i> (2009); Bourguet <i>et al.</i> (2010); Hultgren <i>et al.</i> (2014)
<ul style="list-style-type: none"> proximity to humans 	Hemsworth <i>et al.</i> (1994); Keer-Keer <i>et al.</i> (1996); Beausoleil <i>et al.</i> (2005); Petherick <i>et al.</i> (2009); Mazurek <i>et al.</i> (2011); Bassler <i>et al.</i> (2013)
<ul style="list-style-type: none"> other animals (especially if in mixed social groups) 	Arnone and Dantzer (1980); Terlouw and Rybarczyk (2008)
<ul style="list-style-type: none"> lairage of suckled lambs 	Linares <i>et al.</i> (2008)
<ul style="list-style-type: none"> use of dogs for handling sheep 	Beausoleil <i>et al.</i> (2005); Hemsworth <i>et al.</i> (2011); Zimerman <i>et al.</i> (2013)
<ul style="list-style-type: none"> handling systems that separate/isolate animals from other members of the group before stunning 	Terlouw <i>et al.</i> (2008); Bourguet <i>et al.</i> (2010)
<ul style="list-style-type: none"> fast speed of movement of pigs from lairage to stunning area 	Hemsworth <i>et al.</i> (2002)
<ul style="list-style-type: none"> exposure to heat or cold stress during lairage 	Hunter <i>et al.</i> (1998); Lowe <i>et al.</i> (2002); Debut <i>et al.</i> (2005); Knezacek <i>et al.</i> (2010); Scanes (2016)
<i>Handling and restraint before stunning</i>	
<ul style="list-style-type: none"> handling of poultry by legs and inversion 	Jones (1992); Kannan and Mench (1996)
<ul style="list-style-type: none"> shackling of poultry before electrical stunning 	Kannan <i>et al.</i> (1997); Debut <i>et al.</i> (2005); Bedanova <i>et al.</i> 2007;
<ul style="list-style-type: none"> animals left in stunning pens or restraining facilities longer than necessary, e.g. when the line is stopped during breaks or equipment breakdown 	Cockram and Corley (1991); Probst <i>et al.</i> (2014)
<ul style="list-style-type: none"> escape from the restraining facilities during slaughtering operations 	
<ul style="list-style-type: none"> dragging, tying, shackling or hoisting livestock that are still conscious 	Grandin (2003, 2014); Leary <i>et al.</i> (2016); Omotosho <i>et al.</i> (2016)
<i>Stunning</i>	
<ul style="list-style-type: none"> breathlessness, asphyxia or choking and excitation responses of pigs to carbon dioxide stunning 	Dodman (1977); Forslid and Augustinsson (1988); Raj (1998); Raj and Gregory (1996); Velarde <i>et al.</i> (2007); Llonch <i>et al.</i> (2012)
<ul style="list-style-type: none"> consciousness or recovery from stunning due to inadequate stunning <ul style="list-style-type: none"> incorrect positioning of stunning device 	Anil and McKinstry (1998); Velarde <i>et al.</i> (2000); Njisane and Muchenje (2013); Romero <i>et al.</i> (2017)
<ul style="list-style-type: none"> inadequate current/force 	Anil and McKinstry (1998)
<ul style="list-style-type: none"> more than one stun required 	Miranda-de la Lama <i>et al.</i> (2012); Njisane and Muchenje (2013); Chulayo <i>et al.</i> (2016)
<ul style="list-style-type: none"> recovery from stunning due to delay in exsanguination 	Miranda-de la Lama <i>et al.</i> (2012); Bolaños-López <i>et al.</i> (2014); Romero <i>et al.</i> (2017)
<ul style="list-style-type: none"> recovery from stunning due to ineffective exsanguination 	Anil <i>et al.</i> (2000)
<i>Exsanguination without prior stunning</i>	
<ul style="list-style-type: none"> inverted restraint before exsanguination without stunning 	Westervelt <i>et al.</i> (1976); Dunn (1990); Bourguet <i>et al.</i> (2011a); Lambooij <i>et al.</i> (2012); Bozzo <i>et al.</i> (2018)
<ul style="list-style-type: none"> blood entering trachea after exsanguination without stunning causing irritation and respiratory distress 	Gregory <i>et al.</i> (2009)
<ul style="list-style-type: none"> awareness before loss of consciousness after exsanguination without stunning 	Daly <i>et al.</i> (1988); Anil <i>et al.</i> (1995a,b); Ceci <i>et al.</i> (2017); Cranley (2017)

situations (National Research Council, 2009). Stress responses can only provide evidence of arousal, as similar responses are also seen in response to a variety of negative affective states, including fear and pain (Ralph and Tilbrook, 2016), and are not even specific to negative/aversive situations (Rushen, 1986). The standard method of assessing stress responses is to measure increased activity of the hypothalamic–pituitary–adrenocortical axis (consisting of hypothalamus region of the brain, the anterior pituitary gland located below the brain and the cortex of the adrenal glands located near the kidneys) and the sympathoadrenomedullary system (consisting of the sympathetic nervous system that innervates the heart and other organs and the medulla of the adrenal glands). Increases in hormone concentrations, especially glucocorticoids produced by the adrenal cortex (cortisol in mammals and corticosterone in poultry) and catecholamines (epinephrine/adrenaline and norepinephrine/noradrenaline) produced by the adrenal medulla, heart rate and respiratory rate, and a redistribution of blood flow can occur in response to stressors to assist an animal to respond to challenges that might require exercise. These responses increase blood flow to the muscles and mobilize fat from adipose tissues and glycogen from the liver to increase blood glucose concentration to provide energy sources (Mormède *et al.*, 2007). This is Cannon’s ‘fight or flight’ syndrome (Cannon, 1939) that evolved to enable animals to respond to predators. Activation of the sympathoadrenomedullary system can occur within seconds, whereas the hypothalamic–pituitary–adrenocortical axis responses occur within minutes and can last several hours.

Physiological measures of stress

Animals can show physiological stress responses to a number of procedures undertaken during pre-slaughter and slaughter (Table 2.3). For example, during restraint before stunning/exsanguination, Westervelt *et al.* (1976) recorded a greater respiration rate in calves and a greater heart rate in sheep that were shackled and hoisted versus those restrained on a yoke with their feet elevated off the floor. Stress responses can consist of overt and active behaviour, e.g. vocalization, and increased activity or passivity/withdrawal (immobility or freezing), e.g. tonic immobility and decreased maintenance behaviour (Ewbank, 1985). Some general signs of distress in livestock and poultry are

thought to include tail flicking, head shaking, defecation, urination, shivering, eyelid flickering, head retraction and eye closure, gasping, yawning and vocalization (rate and change in character) (Gregory and Grandin, 1998; Briefer, 2012; Martin *et al.*, 2016).

Compared with measurements made on the farm, several studies have shown successive increases in plasma cortisol concentration after handling, transport, lairage and slaughter (Fordham *et al.*, 1989; Ceci *et al.*, 2017), with the greatest signs of stress (e.g. greater urine concentrations of epinephrine and norepinephrine and greater plasma cortisol concentration) immediately after slaughter (Bourguet *et al.*, 2010). Although each of the pre-slaughter stages can be stressful, whether a stress response occurs can depend on both animal factors and how the procedure is undertaken. For example, pigs that were routinely handled on-farm, transported a short distance, then kept in the lairage for 5 days before slaughter and handled carefully had a lower plasma cortisol concentration at slaughter than those that were mixed, transported for 2 h, kept in lairage for 0.5 h and then moved quickly before electrical stunning and exsanguination (Brown *et al.*, 1998). Handling of pigs from the lairage to the stunning area without the use of electric goads is less stressful than when inappropriate handling consisting of the use of electric goads, shouting by handlers and increased movement of the pigs is used (Hambrecht *et al.*, 2005).

Both genetics and previous experiences affect stress response

The physiological and behavioural responses of animals to the same stressor can vary between individuals and are influenced by the experience and genetics of the animal (Koolhaas and Van Reenen, 2016). For example, pigs heterozygous for the halothane gene had greater plasma cortisol concentrations after transport and after lairage than those that were homozygous negative for the halothane gene (Fàbrega *et al.*, 2002). There can be differences between animals in how they perceive a stressor and differences in response styles to a stressor (Deiss *et al.*, 2009). More excitable cattle have increased stress responses during handling compared with those with a calmer temperament (Curley *et al.*, 2006; Cooke, 2014). Cattle reared extensively have less frequent interaction with humans and are more likely to show expressive

behaviour during handling compared with cattle reared intensively (Fordyce *et al.*, 1985). The social grouping of cattle and the degree and type of handling that they experienced during rearing can affect the plasma cortisol concentration at the time of slaughter (Bourguet *et al.*, 2010). Repeated early gentle physical human contact with calves can reduce plasma cortisol concentration at slaughter (Probst *et al.*, 2012). In pigs that had been reared in a barren environment, de Jong *et al.* (2000) found an increased salivary cortisol concentration after pigs had been mixed, transported and lairaged compared with that measured on-farm before mixing. However, in pigs reared in an enriched environment (larger pens and straw) the salivary cortisol concentration was not significantly increased by these procedures.

Exercise and stress before slaughter can increase muscle activity, resulting in increased post-mortem muscle metabolism and in pigs and poultry in particular, a faster reduction in muscle pH and a slower fall in temperature that reduces meat quality (Terlouw *et al.*, 2012). The relationship between pre-slaughter stress and meat quality is complex. Whether pre-slaughter stress affects meat quality issues can depend on genetics and the carcass handling procedures (Gispert *et al.* 2000; Terlouw, 2005; Terlouw *et al.*, 2008). Warriss *et al.* (1998) did not find a clear relationship between pre-slaughter stress in pigs (as assessed by measurements of cortisol, lactate and creatine kinase at exsanguination) and measurements that characterized PSE meat. However, Choi *et al.* (2012) reported that high post-mortem muscle cortisol concentration in pigs was associated with increased muscle pH₂₄, reduced drip loss and increased tenderness. Increased pre-slaughter stress and/or activity can decrease muscle glycogen stores, resulting in a lower overall post-mortem muscle pH decline and an increased ultimate muscle pH that can affect meat quality (e.g. DFD meat). Foury *et al.* (2005) found positive correlations between post-mortem urinary catecholamines in pigs and muscle pH₂₄. Warriss *et al.* (1998) found signs of stress in pigs with DFD meat, but not all stressed pigs produced DFD meat, and Shaw *et al.* (1995) found greater concentrations of muscle cortisol in pigs with DFD meat than in those with normal meat. Although the presence of meat quality problems could indicate potential welfare issues, the absence of meat quality issues does not necessarily indicate that the animals had not been stressed during the pre-slaughter period.

Interpretation of physiological measures

The relevance of stress measurements in exsanguinated blood collected immediately after stunning as a way of assessing the effectiveness of different stunning methods requires careful interpretation. At slaughter, the sympathetic nervous system can be activated by an increase in intracranial pressure (Chiari *et al.*, 2000) at stunning and by a reduction in blood pressure at exsanguination (Gregory and Grandin, 1998). For example, the concentrations of catecholamines in blood samples collected at exsanguination increase after electrical and mechanical stunning (Shaw and Tume, 1992) and Althen *et al.* (1977) found an increased plasma concentration of epinephrine after pigs were electrically stunned or shot with a rifle, but not after shackling and exsanguination without stunning. Zulkifli *et al.* (2014) reported an increase in plasma norepinephrine concentration immediately after non-penetrating stunning and before exsanguination. However, they did not find a significant effect of penetrating or non-penetrating captive bolt stunning on plasma cortisol concentration immediately after stunning compared with immediately before stunning and there was no effect of stunning compared with exsanguination without stunning. If stunning causes immediate loss of consciousness it will not matter whether a particular stunning method causes sympathetic nervous system activation or not (Grandin, 2014). However, if a slaughter method does not cause immediate loss of consciousness and the animal experiences distress before it dies, an increase in stress may be detected. For example, Caballero *et al.* (1998) found greater signs of stress in cattle following cutting of the spinal cord (putilla) than in those stunned using a captive bolt. Ceci *et al.* (2017) reported greater plasma cortisol concentrations in blood collected during exsanguination in cattle that had not been stunned compared with those that had been stunned using a captive bolt. Chulayo *et al.* (2016) reported greater plasma cortisol concentration in blood collected during exsanguination in cattle that were given more than one captive bolt shot compared with those given one shot.

Fear

A major cause of stress at slaughter is fear of novel stimuli (Grandin, 2013) and fear from social disruption, especially isolation (Boissy, 1995; Forkman *et al.*, 2007). Animals are removed from their familiar

environment on the farm, handled by humans, transported, mixed with unfamiliar animals in the lairage, exposed to novel sounds and odours and then moved to the point of slaughter. Fear is an emotional state induced by the perception of danger (Boissy, 1995). It is associated with escape or avoidance responses to a specific threat that is likely to cause harm (Dawkins, 2017). Anxiety is the emotional state experienced in anticipation of a threat to safety (Ledger and Mellor, 2018). Fear reactions can consist of autonomic nervous system responses such as increased heart rate, reflex withdrawal from the stimulus, and active and passive behavioural responses (Dawkins, 2017). Domesticated animals have maintained their fear responses that evolved as a way of avoiding potential predators (Rushen *et al.*, 1999). Behavioural and physiological responses to fear prepare an animal to deal with danger and include defence (attack, threat), active avoidance (flight, hiding and escape) or passive avoidance (immobility) (Boissy and Erhard, 2014). Other behaviours such as feeding, exploration and social interactions can be inhibited. The characteristics of fearful stimuli are those that would have been associated with a predator, namely movement, suddenness, proximity and unpredictability (Désiré *et al.*, 2004, 2006; Boissy and Erhard, 2014; Boissy and Lee, 2014). Humans can be perceived as potential predators and evoke fear responses due to their height and their quick or unpredictable movement (Rushen *et al.*, 1999; Forkman *et al.*, 2007). Fear of humans motivates animals to move away from handlers, and this response can be used to move the animals in the required direction. However, if excessive fear responses are caused, it can result in handling difficulties such as aggression, immobility or escape behaviour (Gregory and Grandin, 1998; Njisane and Muchenje, 2013). Animals that have been reared in an extensive system with minimal contact with humans are even more likely to experience fear during handling. Handling during rearing can reduce fear responses of livestock to humans, but this depends on the consistency, timing and type of interaction during rearing (Boissy and Bouissou, 1988; Hemsworth and Barnett, 1992). Gevink *et al.* (1998) found that pigs were easier to handle when they were moved out of a lairage pen if they had been subjected to regular handling on the farm.

Animals show individual differences in their fear responses and these can have a genetic basis (Boissy *et al.*, 2005). Individual differences between sheep in the magnitude of their responses (vigilance and high-pitched bleating) to novelty and social isolation

can affect their stress response to slaughter (as measured by the plasma cortisol concentration in exsanguinated blood) (Deiss *et al.*, 2009). Pigs assessed as fearful (using a novel object test) can have a greater serum cortisol concentration at exsanguination following carbon dioxide stunning than those assessed as less fearful (Carreras *et al.*, 2017).

Pigs can show behavioural and physiological responses to the sight and sound of other pigs in distress, but whether their responses indicate that they were distressed by the emotional state of the other pigs is not clear (Düpijan *et al.*, 2011; Goumon and Špinka, 2016). Although subsequent discussion (Edgar *et al.*, 2012) questioned whether the results obtained were sufficiently robust to permit practical application, Anil *et al.* (1996, 1997) concluded that the observation of the stunning and exsanguination of other animals was not stressful/fearful to sheep or pigs waiting for slaughter. There is evidence that animals can be affected by signals such as odours and alarm calls from other animals that have experienced or are experiencing fear (Reimert *et al.*, 2017; Baciadonna *et al.*, 2018). For example, some pigs avoided approaching a feeder sprayed with urine from stressed pigs but not one sprayed with urine from a non-stressed pig (Vieuille-Thomas and Signoret, 1992). In some studies, but not in others, compared with urine from non-stressed cattle, cattle can show increased latency to approach areas containing urine from stressed cattle (Boissy *et al.*, 1998; Terlouw *et al.* 1998). Cattle can show increased sniffing and slower leg movements when approaching urine from stressed cattle or blood collected from a slaughter plant compared with their response to urine from non-stressed cattle or water (Terlouw *et al.*, 1998).

Behavioural responses of fearful animals

Because of the complexity of the mechanisms underlying fear-related responses, it is not possible to attribute specific behavioural responses to fear (Forkman *et al.*, 2007), but one response that has been used is tonic immobility, an anti-predator response seen in poultry and pigs after a handler turns the animal on its side. The animal remains immobile in an apparent attempt to distract the predator. The duration of tonic immobility is thought to be a measure of the fear experienced immediately preceding induction into tonic immobility (Jones, 1986; Erhard and Mendl, 1999; Andersen *et al.*, 2000a) and has been used to assess

fear responses of broilers following transportation to slaughter (Cashman *et al.*, 1989) and to shackling (Bedanova *et al.*, 2007). Fear responses thought to occur in slaughter plants are, for sheep and cattle, a head-down posture (when there is no obvious opportunity for escape from a fearful situation) (Hemsworth *et al.*, 2011), and for pigs and cattle, a reluctance to move (Hultgren *et al.*, 2014) or turning back from their direction of movement (Dalmau *et al.*, 2009b, 2010). Vocalization and changes in the characteristics of vocalization, e.g. loud, high-pitched vocalizations, can occur in pigs when they are aroused/excited (Reimert *et al.*, 2013; Leliveld *et al.*, 2017). Cattle and sheep vocalize when they are socially isolated (Manteuffel *et al.*, 2004; Deiss *et al.*, 2009), and cattle can vocalize when stressed by handling procedures at slaughter plants (Grandin, 1998a, 2001; Hemsworth *et al.*, 2011; Hultgren *et al.*, 2014). Other fear responses can include: piloerection; changes in facial expressions; head and ear position; defecation; urination; and the production of pheromones (Boissy, 1995; Reefmann *et al.*, 2009; Reimert *et al.* 2013).

Hunger and Thirst

Hunger

Hunger is part of an animal's normal daily rhythm associated with meal intake (Roche *et al.*, 2008; D'Eath *et al.*, 2009). There are anatomical and physiological differences in the digestive systems of ruminants, pigs, poultry and humans, but the mechanisms controlling hunger are thought to be similar (Baile and Della-Fera, 1981; Roche *et al.*, 2008). Hunger in animals is likely caused by a lack of gastrointestinal distention, by hormones that are influenced by circulating metabolites and metabolic signals from energy stores that reflect the energy status of the animal relative to metabolic demand, and by time of day. These signals are integrated by the hypothalamus, thalamus and other areas of the brain to produce the feeling of hunger (Tataranni *et al.*, 1999; Roche *et al.*, 2008). Hunger can be identified by an increased motivation to consume feed (Jackson *et al.*, 1999) and by increased activity to seek feed, e.g. foraging behaviour. Animals that have been fasted can show increased signs of arousal and anticipation before feed delivery (D'Eath *et al.*, 2009). However, Saucier *et al.* (2007) found no effects of fasting for up to 24 h on the lying behaviour, exploratory

behaviour or water intake of lairaged pigs. When offered feed, feeding rate is increased, and animals are likely to show increased competition to gain access to the feed (Beattie *et al.*, 2002).

It is normal practice to fast animals before slaughter; and if this period is prolonged, signs of hunger can become exaggerated and detrimental effects can occur. If fasting causes energy reserves to become exhausted (Warriss, 1982; Warriss *et al.*, 1988), this could increase the risk of fatigue and make animals more susceptible to cold environments. In some circumstances, especially if fasting is associated with social mixing, there can be an increased risk of fighting, resulting in skin injury in pigs (Brown *et al.*, 1999; Murray *et al.*, 2001) and bruising in cattle (Dodt *et al.*, 1979). There is some evidence that cattle fasted for 30 h are more susceptible to stressors such as novelty and show greater fear responses to sudden events and handling than those that have not been fasted (Bourguet *et al.*, 2011b; Terlouw *et al.*, 2012). Pigs fasted for 18 h before loading can vocalize more and be more difficult to orientate during loading than non-fasted pigs (Dalla Costa *et al.*, 2016).

Reasons for fasting before slaughter

There are several reasons why animals are fasted before slaughter and they include the following.

- For pigs and broilers, the risk of mortality during transport and lairage can be reduced (Averos *et al.*, 2008; Caffrey *et al.*, 2017).
- The stomach and intestines are not as distended (Bass and Duganzich, 1980; Warriss *et al.*, 2004; Faucitano *et al.*, 2006) and therefore there is less risk of inadvertent puncture/rupture during evisceration and a reduced risk of carcass contamination (Miller *et al.*, 1997; Morrow *et al.*, 2002).
- The amount of faeces produced during transport and lairage is decreased (Gregory *et al.*, 2000; Warriss *et al.*, 2004). This reduces the risk of faecal contamination of the animals and the amount of waste that requires disposal (Fisher *et al.*, 2012).
- There is insufficient time for feed consumed in the period before loading to be digested and converted into muscle and other tissues to justify an economic return from the cost of feeding (Carr *et al.*, 1971; Murray *et al.*, 2001; Kephart and Mills, 2005).
- It is thought that some aspects of meat quality might be improved (Sterten *et al.*, 2009; Faucitano

et al., 2010), e.g. in pigs, a reduction in drip loss (Salmi *et al.*, 2012). However, prolonged fasting can reduce carcass weight (Jones *et al.*, 1988) and reduce muscle glycogen, increasing the risk of DFD meat (Salmi *et al.*, 2012).

- For animals sold by weight, a period of fasting improves the prediction of the carcass weight (Hogan *et al.*, 2007).

The total duration of fasting is affected by the duration that feed is withdrawn on the farm before loading, the duration of transport (in many countries, animals are not normally offered feed during a journey to slaughter) and the duration of lairage without feeding. Even if animals are offered feed in the lairage, the latency to feed and the amount of feed consumed might be reduced by fear associated with: (i) the novelty of their environment, feed and feeding equipment; and (ii) unfamiliar animals in the same pen competing for limited access to feed (Boissy and Bouissou 1995; Dalmau *et al.*, 2009b). Although most animals readily consume feed when it is offered after a journey, a novel environment can decrease feed intake (Cockram *et al.*, 2000).

Thirst

Animals that do not have access to drinking water can become dehydrated during long journeys to slaughter and in hot environments (Arad *et al.*, 1985; Zhou *et al.*, 1999; Hoffman and Lühl, 2012). Thirst is a sensation that arises from dehydration and motivates animals to seek and drink water to maintain homeostasis (McKinley and Johnson, 2004). If thirst is severe and prolonged, it can be associated with significant dehydration and weakness. Thirst can be identified by increased water

intake and reduced latency to drink after a period of water deprivation (Wythes *et al.*, 1980; Jensen *et al.*, 2016). It is initiated by an increase in the osmolality of body fluids, by a decrease in body fluid volume, and is affected by the presence of water in the oral cavity (de Araujo *et al.*, 2003). Dehydration can be assessed by measuring the total plasma protein concentration and plasma osmolality. As dehydration reduces carcass weight (Wythes *et al.*, 1980) and affects skin pliability, thereby making the skin more difficult to remove during carcass processing (Gregory and Grandin, 1998), it is avoided whenever possible. Withholding water during lairage to prevent a distended gastrointestinal tract is not required (Wythes *et al.*, 1985) and livestock (but not poultry) are normally provided with drinking water in the lairage. The susceptibility of different types of animals to dehydration varies. Suckling lambs that have recently been removed from their lactating mothers may not have learnt how to drink from a trough or drinker and are at risk of dehydration if they kept in a lairage too long (Jacob *et al.*, 2006; Velarde and Dalmau, 2012). Adult ruminants are more tolerant of short periods of water restriction and can utilize water from their rumen (Hecker *et al.*, 1964), but pigs are susceptible to water deprivation (Haupt and Yang, 1995).

Discomfort

Examples of potential causes of discomfort in animals during pre-slaughter and slaughter procedures are shown in Table 2.4. Discomfort as an affective state has not been studied extensively. It is likely to be associated with the physical environment and, depending on the cause, could be indicated by restlessness (increased activity such as walking and

Table 2.4. Examples of potential causes of discomfort in animals during pre-slaughter and slaughter procedures.

Examples of potential causes of discomfort	Reference
Inadequate protection from adverse weather conditions	Weeks (2008)
High temperature and/or humidity in lairage	Jacobs <i>et al.</i> (2017)
Exposure to cold conditions in lairage	Dalmau <i>et al.</i> (2016); Jacobs <i>et al.</i> (2017)
Inadequate ventilation in lairage, e.g. increased ammonia concentration	Weeks (2008)
Overcrowding resulting in insufficient floor space for rest or access to feed and water	Kim <i>et al.</i> (1994); Weeks (2008)
Hard or rough flooring in the lairage	Cockram (1990)
Physical pressure from restraint before stunning	Grandin (1998a, 2001); Bourguet <i>et al.</i> (2011a); Velarde <i>et al.</i> (2014)
Inhalation of water during electrical stunning of poultry	Gregory and Whittington (1992)
Electric prod use	Grandin (2001); Hemsworth <i>et al.</i> (2011)

repeated standing up and lying down) (Guesgen and Bench, 2017), irritation or thermal discomfort caused by both heat and cold stress (Ledger and Mellor, 2018).

Fatigue

Although most animals do not show obvious signs of fatigue after long journeys, some animals that arrive at a slaughter plant after certain types of long journey and extended exercise associated with handling will be fatigued (Cockram *et al.*, 2012; Frese *et al.*, 2016). Signs of fatigue in pigs on arrival at a slaughter plant can include an inability to stand and walk, open-mouthed breathing, blotchy red skin and muscle tremors (Fitzgerald *et al.*, 2009). Signs of fatigue in cattle can include reluctance to move, stiff and shortened gait, failure to keep up with the rest of the group and muscle tremors (Thomson *et al.*, 2015; Frese *et al.*, 2016). Exercise during gathering and loading, the work required to maintain posture and balance during transport together with prolonged standing during a journey can cause muscle fatigue. After an extended period of exercise, physiological signs of fatigue can include: (i) a depletion of muscle glycogen and an accumulation of muscle metabolites, e.g. lactate, ammonia and electrolytes (Harman and Pethick, 1994); (ii) muscular damage, identified by leakage of intracellular enzymes, such as creatine kinase, across the cell wall and into the circulation; and (iii) raised body temperature (D'Allaire and DeRoth, 1986; Thomson *et al.*, 2015; Frese *et al.*, 2016). Signs of fatigue are likely to be more apparent in certain individuals and genetic strains, during periods of heat stress, and after transport at high stocking density (D'Allaire and DeRoth, 1986; Fitzgerald *et al.*, 2009; Frese *et al.*, 2016).

Animal Welfare Assessment

An animal welfare inspection or audit for certification or regulation can be undertaken by comparing what is observed at a slaughter plant with a list of minimal requirements (Botreau *et al.*, 2007a). The audit can be conducted using measurable outcomes that can be monitored and benchmarked to evaluate improvements with time (Grandin, 1998b, 2006). In some schemes, an overall evaluation can be made based on the number and severity of the non-conformances observed (Roberts *et al.*, 2012).

However, a comprehensive assessment of animal welfare is a complex task. Animal welfare is a multidimensional concept that cannot be measured directly but only inferred after making and interpreting multiple measurements of the various components thought to affect welfare (Blokhuys *et al.*, 2003). The UK's Farm Animal Welfare Council's 5 Freedoms (Farm Animal Welfare Council, 2009) provide a useful and reasonably comprehensive framework for consideration of the welfare of animals at slaughter plants:

1. Freedom from hunger and thirst.
2. Freedom from discomfort.
3. Freedom from pain, injury and disease.
4. Freedom to express normal behaviour.
5. Freedom from fear and distress.

The consideration of animal welfare in slaughter plants requires a slightly different approach to the assessment of welfare while animals are on the farm. For example, naturalness and positive welfare aspects are not as relevant, and the animals are normally only kept in the slaughter plant for less than a day or overnight. Slaughter can sometimes be arranged to replicate some aspects of natural predation, such as the killing of the animals *in situ* on the farm, while part of their social group. For example, it is less stressful for red deer to be shot while at pasture on-farm than it is for them to be transported to an abattoir for slaughter (Pollard *et al.*, 2002). However, even if the animals are slaughtered in the field, the use of some types of slaughter methods that do not cause instantaneous loss of consciousness is likely to cause greater suffering than methods used in the more controlled and regulated environment of a slaughterhouse (Reinert, 2012). Unless slaughter is undertaken as a form of euthanasia to relieve existing pain and suffering, it does not provide any positive welfare aspects that can be assessed.

Welfare assessment protocols

Welfare assessment protocols that have been or could be used to assess the welfare of cattle at slaughter were reviewed by Wigham *et al.* (2018). Welfare assessment systems are based on the identification of signs/indicators that are thought to reflect an animal's welfare status (animal-based or output measurements) and the risk factors (input measurements of the environment, management, genetics etc.) that could affect the output measurements

(Blokhuys *et al.*, 2008). The risk factors that affect animal welfare at slaughter include the physical environment and the resources available to the animal such as space allowance, feed and water quantity and quality, bedding, etc., and management-based measures that can be assessed by documentation, e.g. staff training records and standard operating procedures. Depending on its characteristics (breed, sex, age, etc.) an animal will respond to these risk factors in varying ways, and their responses are assessed using animal-based measures. Input factors are easier to record than the responses of the animal and are more likely to be consistently recorded over time. Direct animal-based measures are made by observation, examination or inspection of the animals ante- or post-mortem (EFSA, 2012). Examples of animal-based measures are mortality, morbidity, lameness, injuries, body condition, signs of dehydration and the presence of overt behaviour indicative of pain or fear (Barnett and Hemsworth, 2009). Many animal-based measurements made under controlled experimental conditions are difficult to measure under commercial conditions and they often require information about the environment of the animals before they can be interpreted appropriately (Bracke, 2007).

Welfare Quality® system

Velarde and Dalmau (2012) and Dalmau *et al.* (2016) described how the European Welfare Quality® approach that was primarily developed for on-farm assessment could be used to assess the welfare of pigs and cattle at slaughter. The Welfare Quality® assessment scheme is based on 12 key criteria: (i) absence of prolonged hunger; (ii) absence of prolonged thirst; (iii) comfort around resting; (iv) thermal comfort; (v) ease of movement; (vi) absence of injuries; (vii) absence of disease; (viii) absence of pain induced by management procedures; (ix) expression of social behaviour; (x) expression of other behaviours; (xi) good human-animal relationship; and (xii) absence of general fear. In this scheme, data is collected on an animal unit and then converted into a score to evaluate the degree of compliance with these criteria. The scores obtained at this criterion level are then collated to assess unit compliance with four welfare principles (good feeding; good housing; good health; appropriate behaviour). Finally, these principle scores are used to make an overall evaluation of the unit

as not classified, acceptable, enhanced or excellent (Botreau *et al.*, 2009). To express the overall welfare status of a group of animals in a single integrated score or evaluation requires the interpretation and balancing of different types of data. Unfortunately, there is no standardized way of doing this and judgements on which criteria to use and how to weigh their relative importance involves a degree of subjectivity (Spoolder *et al.*, 2003; Botreau *et al.*, 2007a,b; de Graaf *et al.*, 2018).

Welfare Quality® assessment protocols have been produced for cattle, pigs and broilers that incorporate some welfare assessments of finishing pigs, fattening cattle and broilers at the slaughter plant (Welfare Quality®, 2009a,b,c). All of these protocols assess the effectiveness of stunning. Observations are made during unloading, handling, lairage, slaughter and post-mortem (Dalmau *et al.*, 2009b). The Welfare Quality® assessment protocols for pigs and cattle differ slightly, but in general, they score animals during unloading (by quantifying the frequency of slipping, falling, reluctance to move or turning back). In the lairage, they score the availability of food, the number of functional and clean drinking water sources, space allowance, the type of flooring, risk of injury and availability of bedding. Ante-mortem animal-based measurements used for cattle and pigs are scores for mortality, lameness and vocalizations and, for pigs only, signs of thermal discomfort (shivering, panting, huddling) and signs of respiratory disease. For cattle, the use of handling devices and direct physical contact by the handler together with struggling, kicking and jumping in the stunning box are assessed. Measurements on broilers include the duration of feed and water withdrawal, mortality, crate stocking density, panting and flapping on the shackle line and the recording of any pre-stun electric shocks. Some post-mortem measurements of pathology are also made. Brandt and Aaslyng (2015) used the Welfare Quality® protocol and additional measurements for the assessment of the welfare of pigs from the collection area on a farm during loading, transport, unloading, lairage, movement to stunning, stunning and exsanguination. Due to insufficient data to develop an expert consensus, a method for aggregation of the welfare scores at a slaughter plant was not developed during the original welfare quality project (Dalmau *et al.*, 2016). However, Brandt *et al.* (2017) used the Welfare Quality® protocol, plus additional assessments (heart rate, duration of each stage, whether

pigs were mixed, postures during lairage and how the pigs were handled), to make an overall assessment.

Use of animal-based measurements

Even if an animal-based measurement can be collected with relative ease, to be useful it should be valid, i.e. provide accurate information about a relevant welfare outcome. The specificity of an animal-based measure will depend on whether it responds to a single welfare factor or whether it relates or responds to several different factors. Some animal welfare outcomes that can be made at the time of slaughter or post-mortem represent the cumulative effect of various pre-slaughter factors on the animals, and their magnitude can be the consequence of the duration and intensity of a risk factor. Even though it is not always possible to attribute changes in these measurements to a particular factor or to relate them to a particular affective state, they can provide useful information on the influence of the overall pre-slaughter process on animal welfare. Examples of this type of measurement are: vocalizations (Grandin, 1998a); blood composition and temperature sampled during exsanguination, e.g. blood lactate concentration and creatine kinase activity; meat quality issues, e.g. bruising, skin damage, PSE meat, DFD meat; and mortality (Gispert *et al.*, 2000; Brandt and Aaslyng, 2015). Although meat quality problems that are not caused by injury can be caused by factors associated with less than optimal welfare conditions, they are not reliable indicators of animal welfare. Rocha *et al.* (2016) recorded a range of pre-slaughter procedures in pigs and only found correlations between increased frequency of slipping at unloading and in the stunning chute area and increased drip loss and light reflectance, and between the use of electric prods in the stunning chute area and greater light reflectance of the longissimus lumborum muscle.

Defining the reasons why an animal welfare assessment is performed can assist in deciding whether it is necessary, appropriate and feasible to attempt to undertake all possible measurements and whether an overall welfare assessment, as used for an on-farm assessment, is a useful concept in the context of a slaughter plant. If the assessment is conducted to provide an assurance on the end product, or if the slaughter plant is part of an integrated company that has control of the production

and transport of the animals, then an overall assessment can be useful. Where responsibility for the various welfare issues is divided, the aggregation of different types of Welfare Quality® measurements into an overall score may not be as useful. Some of the welfare issues assessed in the Welfare Quality® protocols are primarily related to on-farm issues (such as genetic susceptibility to fear and stress, lameness, the presence of pathology and decisions on fitness for transport) and some of the issues are related to how the animals are transported. These aspects may not be directly under the control of the slaughter plant management.

Choosing welfare measurements

Only some of the list of potential measurements that could be made in an attempt to assess animal welfare at slaughter plants could be considered 'feasible' to record routinely in a commercial environment (Llonch *et al.*, 2015; Losada-Espinosa *et al.*, 2018). As discussed by EFSA (2012), the selection of which measurements are appropriate will depend on a number of factors, including the skills of the assessor, the conditions under which the information is collected, the time available and financial constraints. For example, in one study, the time taken to complete the Welfare Quality® assessment protocol in a pig slaughter plant was 5.5 h (range 4.3–7.3 h) (Dalmau *et al.*, 2009b). The criteria for selection of a welfare indicator will also depend on issues such as the validity, sensitivity, specificity and robustness of the measurement (EFSA, 2012). The robustness of an animal-based measurement is influenced by how the measure is affected by changes in the environment, the person making the measurement and when it is taken. Repeatability and reliability of a measurement, i.e. the agreement between repeated measurements of the welfare outcome on the same sample by the same assessor (intra-observer) or a different assessor (inter-observer), affect the reproducibility of the assessment (EFSA, 2012). Inter-observer reliability is improved if there are not too many categories to observe and score (Grandin, 2017b). For example, Dalmau *et al.* (2010) assessed the repeatability of observations to assess lameness and the frequency of slipping and falling during unloading and movement of pigs to a lairage pen. They found it difficult to observe lameness until unloading was complete and the pigs were in the passageway. They also found it difficult to assess several variables simultaneously. The ability to

observe and measure many animal-based measurements can be affected by: (i) fast processing speeds; (ii) the design and operation of facilities; (iii) the necessity to avoid interference with commercial operations and the movement of animals (Berg, 2012; Payne *et al.*, 2017; Wigham *et al.*, 2018); health and safety concerns in relation to (iv) the movement of animals and equipment; compliance with food safety regulations (e.g. movement between the lairage and the slaughter floor); difficulties in ensuring continuity of observations and (v) measurements on the same batch of animals during each stage of slaughter; and (vi) the necessity to be present at specific times outside of the normal working day. When measurements are made on a sample of animals, it is essential that the sample is unbiased and representative of all of the animals that pass through the slaughter plant. With automatic recording of measurements and development of techniques for precision livestock farming, an increased number of animal-based measurements, for example some of those discussed by Brandt and Aaslyng (2015), may become feasible (Støier *et al.*, 2016). Video recordings made for auditing and verification of slaughterhouse compliance with legislation and guidelines can be useful, especially if it becomes possible to have automated analysis of animal movements (Gronskyte *et al.*, 2016).

Conclusions

The animals slaughtered for food can experience a range of mental states, including pain, fear, distress, hunger, thirst, fatigue and discomfort. This chapter highlighted how pre-slaughter and slaughter procedures can affect the occurrence of these potential welfare issues. Subsequent chapters will describe approaches to avoid and mitigate suffering when animals are slaughtered. Animal welfare research continues to refine methods for identifying when animals are experiencing a negative welfare state, how to assess animal welfare at slaughter plants, how to provide optimal care for animals during pre-slaughter management and how to minimize the risks of pain and distress during stunning and slaughter.

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3

Tradeoffs Balancing Livestock and Poultry Welfare Concerns with the Commercial Reality of Slaughter

TEMPLE GRANDIN*

Department of Animal Science, Colorado State University, USA

Summary

When working with commercial companies, it is often more effective to actually achieve 70–80% of the desired welfare improvements than attempt to achieve 100% perfection and accomplish nothing. There are conditions that cause suffering that are always wrong and in these situations there is never a tradeoff. Some examples would be beating animals, restraint methods that cause injury, throwing or dragging animals or breaking tails. Government officials, managers of meat-buying supply chains and abattoir managers must always stop these abusive practices. However, there are often situations where there are legitimate welfare tradeoffs. Choice of stunning method is a major area of controversy. Electrical stunning induces instantaneous unconsciousness, but the handling methods to position the pigs or birds are more stressful than with gaseous stunning. When controlled atmosphere stunning is used, the pre-slaughter handling method causes much lower stress, but this must be balanced against the behavioural reaction to a slower induction of unconsciousness. During the induction phase, the animals may be exposed to aversive stimuli. This chapter will help readers make decisions about tradeoffs.

Learning Objectives

- Learn that when decisions are made about animal welfare, there are sometimes tradeoffs.
- List bad practices that are *never* acceptable and there are no tradeoffs.

- Discuss differences in animal behaviour that can have a detrimental effect on handling.
- Learn to balance handling stress versus stun method stress when evaluating electrical or controlled atmosphere stunning systems.
- Welfare assessment methods used in commercial programmes often have to be simpler than methods used in research.

Introduction

I have been designing equipment and working with abattoirs on improving animal welfare for over 40 years. My projects have ranged from huge US facilities to smaller operations in Europe, South America and Australia. To make real improvements in commercial abattoirs, I learned that it is often more effective to actually achieve 70–80% of what I want. If I had attempted to get to 100% improvements, I may have been less likely to have achieved anything.

There have been situations where equipment I had designed made big improvements in the welfare of livestock at abattoirs. In other situations, other people who subsequently visited the plant were still highly concerned about welfare. This was due to either employees not operating the equipment correctly or the wrong type of animal being handled in the equipment. In the late 1970s I was hired to design a system that would replace the worst shackling and hoisting system used on cattle for religious slaughter without stunning. This US abattoir was horrible. Almost every steer bellowed

* Email: cheryl.miller@colostate.edu

when it was jerked out of the box and hung up by one leg. This is still legal in the USA, because religious slaughter has legal exceptions to protect religious freedom (FSIS, 2017). The exemptions cover both slaughter without stunning and the restraint methods.

The plant's engineering department and I brainstormed to invent a better system to eliminate cruel shackling and hoisting of 150 cattle per hour (Grandin, 1980). We did this project before I had commercially developed the centre track (double rail) restrainer in the mid-1980s (Grandin, 1988a, 1993). Newer headholder and restrainer systems are much better than my early system (Grandin, 1993). When I look back on this older system, it was primitive compared with my more recent systems. The equipment was far from perfect, but it was a huge improvement compared with dragging live cattle around with chains. After the cattle were hung up, almost 100% of them were bellowing. Working on this early system also showed future clients that I was capable of designing even better systems.

Where Do You Draw the Line?

This is a chapter about tradeoffs. How do you draw the line to determine tradeoffs from an ethical perspective? For me to participate in changing a system that is really terrible, I draw the line at a 70–80% improvement. I would not have used my design expertise to design a slightly better shackle and hoist system. One reason I chose the 70–80% cutoff was that it was attainable in this particular slaughter plant. I remember big discussions with the plant engineer. He raised Angus cattle and he told me he would *never* bring his cattle to the old shackle and hoist system. After the new system was installed, he actually did bring his cattle to this abattoir. There was a joint decision between the engineer and me on what was acceptable. How was this decision made? Our goal was to eliminate the constant bellowing and struggling of tortured cattle. The new system achieved this. Compared with the old way, there was a huge improvement. To sell the expensive new system to plant management, we gave them an analysis on labour savings and safety for employees. To sell future systems, I documented the reduction in employee injuries.

It is Easier to Define Where There is Never a Tradeoff

In my work, I find it is often easier to clearly define what is not acceptable and where there are no tradeoffs (Grandin, 2014). The shackling and hoisting system described above should never be used. People who work in supply chain management buying meat often use terms such as critical non-compliances or non-negotiables for practices that are never allowed. There are certain bad practices that must be eliminated. There should never be tradeoffs with these practices; they should be banned. All the countries that participated in creating the World Organisation for Animal Health (OIE, 2018) welfare standards and the creators of many other government and private standards agreed that the following handling and transport practices are never acceptable.

- Beating, throwing or kicking animals (Defra, 2015, 2019; NAMI, 2019; OIE, 2018).
- Allowing livestock to die from either heat or cold stress during transport or handling. Some examples are parking a truck in the hot sun which causes death losses, or failure to cover a truck to prevent death from cold stress.
- Poking out eyes or cutting tendons to restrain animals (OIE, 2018).
- Restraining conscious mammals by hanging them upside down by the feet or legs (Defra, 2015; OIE, 2018).
- Moving animals by poking sensitive areas such as the rectum or genitals (NAMI, 2019; OIE, 2018).
- Deliberately slamming gates on animals or knocking animals down with gates (NAMI, 2019). Dragging pigs or other livestock with powered gates (FSIS, 2017).
- Multiple repeated shocks with an electric prod (goad).
- Transport of female animals that are likely to give birth during transport (Council of the EU, 2004; Defra, 2015; OIE, 2018).
- Breaking tails to move animals (Defra, 2015; OIE, 2018).
- Overloading vehicles to the point where it is impossible for a fallen animal to get back up, which results in it being trampled by other livestock.
- Immobilizing conscious animals with electricity (Grandin *et al.*, 1986; Pascoe, 1986; Defra, 2015; OIE, 2018). This must not be confused

with proper electrical stunning that causes instant insensibility.

- Deliberately driving animals over the top of other animals (NAMI, 2019; OIE, 2018).
- Dragging, dropping or throwing conscious animals during slaughter or transport (FSIS, 2017; OIE, 2018).
- Puntilla: severing the spinal cord to immobilize animals (Defra, 2015; HSA, 2016; OIE, 2018).

Determining Cut-off Points for Tradeoffs for Livestock Handling in Slaughter Plants

In other situations, the cut-off point for a trade-off is less clear. There are three variables that have an effect on livestock welfare in races and alleys: (i) the skill level of the stock people handling the animals; (ii) the behavioural characteristics of the livestock; and (iii) the design of the facility. A system that could be operated with a high level of welfare in one situation may be highly detrimental to welfare in a different situation. Examples of conditions that would be detrimental to welfare would be excessive electric prod use, animals falling down or beating of animals for refusing to move. In this introductory chapter, examples will be provided to illustrate tradeoffs between the different components of a system.

People Want the New Piece of Equipment More Than Making the Effort Required for Good Management

During a long career, I have found that selling a fancy new piece of equipment is much easier than getting people to operate it correctly. If I have a choice between excellent management and older adequate equipment or a new state-of-the-art facility with poor management, I will always choose the older system that has a good management. Buying new equipment is easy because it is a one-time expense. Good management requires hard continuous work. Management is never done. It requires effort all day, every day. Attention to details and monitoring of procedures must be continued every day. It is not a one-time fix that some people think they can get with new equipment. I have a saying, 'People want the new thing more than they want the management.'

Tradeoff in Decisions on Race, Alley and Handling Facility Design

A facility design that may work well in one situation may be really poor in another. A simple handling system that may be used with a high level of welfare for tame cattle that are trained to lead could be very detrimental for the welfare of extensively raised wild cattle with large flight zones. There have been undercover videos of extensively raised cattle or sheep being handled in slaughter facilities that had been designed for tame animals. The slaughter plant had no chutes, single file races or restraining equipment to hold the wild livestock. The lack of the right equipment resulted in animals slipping on the floor, falling and serious abuse by the people. To correct these problems would have required construction of races, chutes and other systems shown in other chapters of this book. Abattoir designs for wild extensively raised cattle, bison and other livestock are shown in Grandin and Deesing (2008) and Grandin (2014). A basic principle is that extensively raised cattle and sheep that have not lived in close contact with people will require more expensive and elaborate facilities for handling, restraint and unloading transport vehicles. For tame livestock that are trained to lead, a race system may not be required.

Skill-dependent versus Less Skill-dependent Handling Facilities

When stock people are highly knowledgeable about the behavioural principles of livestock handling, simpler economical facilities may be very effective and provide good animal welfare. At an abattoir, it would be difficult to train people to the skill level that is described below. The author watched six wild Karakul sheep being herded by two very skilled stock people who moved them around the perimeter of a corral and expertly restrained them for injections behind a long gate. The sheep were moved calmly by two handlers, who worked the edge of the flight zone and stood at the correct positions. Their rudimentary corral system had no race and forcing pens. It would have been terrible if it had been used by less skilled people. In a place with high employee turnover or less skilled people, a system with races, alleys and a forcing pen would have been required. There has been increasing interest in learning low-stress cattle handling methods and an emphasis on using simpler facilities (Kidwell,

2011; Burt, 2008). People who successfully adopt this approach must develop their stock handling skills to a high level. This often requires several weeks of dedicated practice. To summarize, handling facilities can be either simple economical and highly handler-skill dependent, or more expensive and less dependent on the skill of the stock persons. The latter approach is recommended for abattoirs.

Condition of Livestock or Poultry Arriving at the Slaughter Plant – No Tradeoffs

To prevent suffering, producers and livestock dealers must deliver to the abattoirs an animal that can be easily handled (Grandin, 2017). Severely debilitated or sick livestock are impossible to handle while still maintaining good welfare. In Chapter 4, Michael Cockram discusses problems with old cull cows arriving at abattoirs in very bad condition. Another type of animal that is almost impossible to handle in a low-stress manner is the neonatal (bobby) dairy calf. When Holstein calves are a day old, they do not walk easily. Before dairy calves are shipped, they should have a dry navel cord and be able to walk easily without assistance from a person. The best way to improve neonatal calf welfare is to fatten them into larger steers or bulls that are easier to handle. Early in my career, I made the mistake of attempting to use engineering methods to handle neonatal calves that did not walk easily. Conveyors in the floor were not an effective solution. I tried this and they do not work. The solution is to bring animals to an abattoir that can walk easily. The problem must be fixed at the farm. Some of the worst animal welfare problems I observe in an abattoir are problems that must be fixed at the farm.

Livestock Behaviour Tradeoffs

Cattle and other livestock that have become accustomed to people walking through their pens will be much easier to handle in a low-stress manner at an abattoir. The livestock producer should do some work to improve the ease of handling of their animals when they arrive at a slaughter plant. A review of the literature clearly shows that acclimatizing livestock to handling will make them easier to handle at the abattoir (Abbott *et al.*, 1997; Geverink *et al.*, 1998; Krebs and McGlone, 2009). The question is: how much work should the farmer be required to do to get their animals acclimatized to

handling to prevent them from going berserk in the novel environment of a slaughter plant? Often simple procedures on the farm will improve the behaviour of cattle or pigs. These include walking through pens on foot to teach the pigs or cattle to move away quietly. It is my opinion that producers can easily do this. Animal-based outcome measures at the abattoir can be used to determine which producers have animals that are difficult to handle. Some of the measures that could be used to identify problems are: (i) baulking, refusing to move forward; (ii) turning back; (iii) falling; (iv) vocalization; and (v) electric goad use (Grandin, 1998a,b; Welfare Quality, 2009; Losada-Espinoza *et al.*, 2018). These assessments will be discussed further in Chapter 6.

Differences in Animals: Breed and Genetic Effects

The breed of cattle, sheep or pigs can have an effect on temperament and behaviour during handling (Baszczak *et al.*, 2006). This may make them more difficult to handle at the abattoir. Managers need to work with producers to help prevent handling problems at slaughter plants. More excitable animals exit more rapidly from squeeze chutes (crushes) and struggle more during restraint (Café *et al.*, 2011). Some animals are more excitable and have a higher startle response when they are suddenly introduced into a novel environment (Grandin, 1997). Animals with more excitable genetics may be calm and easy to handle when they are in a familiar environment on the home farm, but they may become highly agitated when brought to a slaughter plant or auction. Deiss *et al.* (2009), Bourquet *et al.* (2010) and Terlouw *et al.* (2012) conducted studies that showed that when temperament was tested on the farm, the novelty of the new environment at a slaughter plant caused more stress in animals that were more excitable than others. Agitation in animals during handling is caused by fear. The fear circuits in animals' brains have been mapped (Panksepp, 2010; Jones and Boissy, 2011; Morris *et al.*, 2011; LeDoux, 2012). Breed differences in behaviour during handling may be due to genetic differences in fearfulness.

Acclimatizing Livestock to Handling Procedures

Acclimatizing livestock to handling will require the producer to do some work to produce an animal

that will have better welfare at the abattoir. Animal memories of previous experiences are very specific. If a horse becomes habituated to a blue and white umbrella, that learning will not transfer to an orange tarp (canvas) (Leiner and Fendt, 2011). Taming ewes to contact with people did not generalize to other procedures such as handling, shearing or movement through a race (Mateo *et al.*, 1991). If an experience that an animal will have in the future is similar to a previous experience, the animal may be able to generalize and be less stressed. Stress caused by moving through a loading ramp can be reduced by training pigs to go through alleys and ramps. Abbott *et al.* (1997), Geverink *et al.* (1998), Lewis *et al.* (2008) and Krebs and McGlone (2009) all did research that shows very clearly that pigs can be acclimatized to handling, which will make them easier to move in the future. Further studies with cattle showed that carefully acclimatizing cattle by moving them through yards and corrals reduced stress at the slaughter plant (Petherick *et al.*, 2009). The reactions of animals indicate that their memories are sensory based and stored as specific images or sounds (Grandin and Johnson, 2005). Cattle differentiate between a person on a horse and a person walking on the ground. Extensively reared cattle that have been handled exclusively on horseback may have only a 1 m flight zone, but when they first encounter a person walking on the ground at an abattoir, their flight zone may expand to 10 m. This can be dangerous for a handler in a small pen, because the animals may run wildly back and forth or attempt to leap the fence to get away from the person. The cattle perceive the person on foot as novel and frightening and the person on a horse as familiar and safe. Ideally cattle should be acclimatized to being moved on foot before they arrive at slaughter plants (Grandin and Deesing, 2008).

A similar problem can occur in pigs or cattle that are raised indoors. The animals differentiate between a person in the alley and a person walking through their pens. To produce calm animals that will be easy to load on to trucks and handle at an abattoir requires people walking through their pens during the entire fattening period. This will get the animals accustomed to moving quietly away when a person walks through them. Pigs that first experience a person in their pens on the day they are shipped are more likely to be difficult to handle. They may bunch together and squeal.

Acclimatization to a person walking through them is especially important with more excitable genetic lines. In the USA, the large integrated pork companies have a standard procedure that instructs people to walk through the finishing (fattening) pens every day.

Handling Bulls

Another factor that can affect animal handling is whether or not animals are socialized to other animals. Intact bulls that have been reared on small farms where they are always kept tied by a halter will often fight and mount each other when they are put in group pens. Fighting and mounting may be more severe compared with bulls reared in groups. Bulls reared together in a group pen or on pasture can be penned together with their herd mates at the slaughter plant. Fighting and mounting may be severe if bulls from different rearing pens are mixed. Bulls assessed as having low fear responses had more mounting than bulls with higher fearfulness (Mark Deesing, 2013, personal communication).

Livestock Breeding for Productivity Tradeoffs Affects Welfare

Producers have been breeding animals and using production methods to achieve greater amounts of meat or milk. Pushing the biological limits for more and more productivity can cause handling and welfare problems at the abattoir. At what point has pushing productivity gone too far? I suggest using outcome measurements at the abattoir such as lameness (mobility) scoring and panting scoring for heat stress (Welfare Quality, 2009; Grandin, 2017). Outcome measurements will be discussed in more detail in Chapter 12.

Genetic abnormalities can also contribute to handling and transport problems. Murray and Johnson (1998) reported that in pigs with the porcine stress syndrome (PSS) gene the death losses during transport were 9.2% in homozygotes, 0.27% in heterozygotes and 0.05% in PSS gene-free animals. Problems with the stress gene will vary in different countries. In the USA, a very low percentage of pigs carry the stress gene. Ninety-three per cent of pigs in midwestern US markets were homozygous negative (Ritter *et al.*, 2007). Indiscriminate selection for production traits such as rapid growth may result in a failure to select

against structural leg defects. At a slaughter plant, the author made observations that showed that half of the market-weight pigs were lame (Grandin, 2014). The lameness was due to hereditary poor leg conformation. The pigs either had straight post-legged joints or their ankles were collapsed and they were walking on their dew claws. Ten years later, observations at the same abattoir indicated that the leg problems had been corrected by the elimination of one of their hybrid boar lines. The pigs I observed weighed between 270 and 290 lbs (123–132 kg) and all the pigs at this abattoir were ractopamine (beta agonist) free. They walked easily and were willing to trot during truck unloading. Selection for small feet in pigs to satisfy a specialized Asian market may also increase the percentage of lame pigs.

Tradeoff: Growth Promoters versus Welfare

Both research and my own observations show that high doses of beta agonists such as ractopamine and zilpaterol may also cause handling problems. Marchant-Forde *et al.* (2003) reported that pigs fed high doses of ractopamine were more difficult to handle. Ractopamine at high doses can also cause hoof lesions and fighting in pigs (Poletto *et al.*, 2009, 2010). Further research has shown that problems with ractopamine in pigs are related to high dosage and physical exertion. When pigs are fed doses over 5 mg/kg per day, they may be more difficult to handle (Ritter *et al.*, 2017). The percentage of non-ambulatory pigs may increase when pigs fed 20 mg/kg are handled in an aggressive manner (James *et al.*, 2011; Peterson *et al.*, 2015; Ritter *et al.*, 2017). I have observed feedlot cattle that had been fed beta agonists that were both lame and heat stressed at the slaughter plant (Grandin, 2010, 2015). Cattle fed ractopamine for 28 days at a dose of 400 mg/day had a higher percentage of lame animals arriving at the abattoir (Hagenmaier *et al.*, 2017a,b). This experiment was conducted during hot summer weather. The temperature was 31°C. Other research has also shown that cattle and sheep fed beta agonists had signs of heat stress and higher body temperatures (Marcia-Cruz *et al.*, 2010; Vogel, 2011. In one very severe case, feedlot cattle fed high doses of zilpaterol had their outer hoof shells fall off (Thomson *et al.*, 2016). I learned that the cattle originated from a feedlot that fed both high doses of zilpaterol and a diet high in potato

starch. Heat stress signs and lameness were sometimes more likely when the outdoor temperature was over 32°C (90°F). Signs of severe heat stress in cattle include open-mouth breathing (Mader *et al.*, 2005) followed by increased panting and, when the tongue becomes further extended, the internal body temperature of cattle rises (Gaughan and Mader, 2016). Loneragan *et al.* (2014) reported that feeding beta agonists increased death losses of cattle during the warmer summer months. I have observed that the detrimental effects were very uneven. A few animals in a group had severe heat stress and were reluctant to move. However, many of the other animals behaved normally. This may be due to uneven feed mixing, some cattle eating more and receiving a much higher dose or individual differences in ability to respond to heat. For example, cattle with black hides get hotter during hot weather compared with cattle with light-coloured hair.

Making Sensible Decisions on Beta Agonist Use

There is a tradeoff between welfare and sustainability. Beta agonists reduce the feed required to fatten an animal (Boles *et al.*, 2012). Some importing countries have banned beta agonists. From a welfare standpoint, outcome measures of lameness and heat stress should be used to prevent producers from using doses that are too high. This is especially a problem when the weather is hot.

In beef, the use of either ractopamine or zilpaterol will make meat tougher (Lean *et al.*, 2014). If the entire animal is going to be used for hamburgers or meatballs, this would not matter. In countries where beta agonists are permitted, people working in the lairage should be monitoring cattle for lameness or reluctance to move. A simple four-point scoring system can be used (Grandin, 2015; Edwards-Callaway *et al.*, 2017): (1) = normal; (2) = lame, keeps with walking group; (3) = lame, does not keep up; and (4) = almost a downer.

Scientific studies, my own observations and reports from lairage managers all indicate that welfare problems in cattle are related to hot weather, high doses of beta agonists and physical exertion. In pigs, problems are related to high doses and physical exertion. Cattle on beta agonists should also be monitored for heat stress. Cattle at rest in a lairage should breathe with their mouths closed. If the mouth is open, they have severe heat stress (Gaughan and Mader, 2016).

Productivity Tradeoffs and Preventing Bad from Becoming Normal

The animal's biology has been pushed too far with either genetic selection or growth promotor substances if: (i) death losses increase; (ii) handling becomes more difficult; (iii) a higher percentage of animals are lame; or (iv) there is a greater percentage of animals showing signs of heat stress. Everybody needs to be careful to prevent bad conditions from slowly increasing and nobody noticing it. I call this 'bad becoming normal'. Surveys of dairy producers showed that they often underestimated the percentage of lame dairy cows by half. In the USA, beef cattle are being fed to heavier weights at younger ages. This may have increased the small percentage of beef cattle that die of heart failure before slaughter. At what point has pushing the animal's biology gone too far?

Electrical Stunning versus CO₂ Stunning Tradeoff for Pigs and Poultry

When animal welfare is being evaluated at a slaughter plant, both the stunning method and the handling methods associated with it should be evaluated as an entire system (Grandin, 2014). There are tradeoffs between the different parts of the system (Velarde and Raj, 2017). A good example is methods for stunning and handling pigs and chickens.

In both species, electrical stunning will produce instantaneous unconsciousness (Croft, 1952; Gregory and Wotton, 1990; Lines *et al.*, 2011) but handling to position the animal is more stressful than for gaseous stunning. When chickens are electrically stunned, each bird is handled by a person and hung on a shackle. Hanging birds inverted on a shackle is highly stressful (Kannan *et al.*, 1997; Bedanova *et al.*, 2007). There is a new European system where the shackles are eliminated but each bird still has to be individually handled at the slaughter plant. From a handling standpoint, controlled atmosphere stunning is far superior. The birds enter the stunner in the transport containers and handling by people at the abattoir is eliminated. Since the gas used for stunning (CO₂) does not induce instantaneous insensibility, the question is: how much stress and discomfort does the animal have before it loses consciousness? Different researchers have reported different results. The stress of anaesthesia induction has to be balanced against the reduction in stress by eliminating

handling of individual birds at the slaughter plant. The author's opinion is that some discomfort during anaesthesia induction such as gasping and head shaking may be acceptable as a tradeoff against greatly lower handling stress. If the animals show escape movements and attempt to climb out of the container, the distress of induction is so severe that the system should not be used.

For poultry, five-stage CO₂ systems, where the level of CO₂ is slowly raised, are being used commercially (see Chapter 8). Gerritzen *et al.* (2013) concluded that the welfare of the chickens was overall improved compared with electrical water-bath stunning. To reduce the aversiveness of the CO₂ the container containing the chickens moves through five stages at 20%, 30%, 35%, 40% and 60% CO₂. There are commercial systems with more steps. Some commercial systems use 90% CO₂ at the final stage to ensure death of all the birds. I have observed anaesthesia induction in two of these systems and it is my opinion that they are a good tradeoff. The entire cycle to move the birds through the system is 6 min. Commercial systems must be closely monitored to prevent the time in the system from being speeded up. Speeding up movement through the machine could be very detrimental to animal welfare.

Gas mixtures that cause escape movements are not acceptable (see Chapter 9). In an abattoir, the reactions of poultry or pigs should be observed and monitored. Either a video camera or windows can be used. There are genetic differences in how pigs react to CO₂. Purebred Yorkshires (Large Whites) have a peaceful induction (Forslid, 1987) but some genetic lines violently attempt to escape when they first contact the gas (Grandin, 1988b). After the animal loses posture and the ability to stand, it has lost consciousness (Benson *et al.*, 2012). Kicking and convulsions after loss of posture are not a welfare concern.

In pigs, group CO₂ systems can reduce handling stress because pigs do not have to line up in single file races. This makes it possible to totally eliminate electric prods. Electric prod use, jamming and other aversive events during the last 5 min before slaughter increase lactate levels and lead to poorer pork quality (Edwards *et al.*, 2010a,b). Cattle are a species that will walk naturally in single file, but pigs may become more stressed when they have to line up. When single file races are used for pigs by highly skilled stock people, the use of electric prods can be reduced to 5–10% of the animals (Grandin,

2012). In this situation, welfare may be acceptable. The tradeoff is that electrical stunning causes no discomfort, but the handling system may be more stressful for the pigs compared with group handling with CO₂ stunning. Both the stunning method and the handling system should be evaluated together. The stress of handling has to be balanced against the aversiveness of the stunning method (Table 3.1).

High Amperage versus Low Amperage Electrical Stunning Systems for Poultry

From an animal welfare standpoint, an electrical stunning system that simultaneously induces unconsciousness and kills the animal by cardiac arrest is preferable to a system that induces a temporary period of unconsciousness. This is why the European Union and the OIE require 100 milliamperes per bird for broilers (EC Council Regulation 1099/2009; OIE, 2018; Defra, 2019; EFSA, 2019). Use of the EU standards will induce cardiac arrest (Gregory and Wotton, 1987; Berg and Raj, 2015; Bourassa *et al.*, 2017).

In many countries, such as the USA and Brazil, lower amperages are used to prevent haemorrhages in the breast meat (Sirri *et al.*, 2017). I have visited poultry slaughter plants in Brazil and the USA. At one abattoir, the stunner had settings labelled ‘export’ with high amperage settings and ‘domestic’ with lower settings. Electrical stunners that do not induce cardiac arrest are also used for halal (Muslim) slaughter (Sabow *et al.*, 2017). Muslim religious authorities want the bird to die after the throat cut.

To prevent meat damage, low amperage systems that do not induce cardiac arrest are a commercial reality. I have worked with abattoirs that have these systems. To prevent birds from regaining consciousness, the automatic bleed machine was moved close to the stunner exit to shorten the stun-to-bleed time. This solved many problems with birds regaining consciousness. Research has also shown that using higher electrical frequencies and amperages can reduce meat damage (Girasole *et al.*, 2015). However, birds stunned at 650 Hz showed more signs of ineffective stunning than those stunned at 300 Hz (Siqueira *et al.*, 2017). When high frequencies are used, the period that the bird remains unconscious will be shorter (Siqueira *et al.*, 2017).

Tradeoffs Between Environmental Sustainability and Animal Welfare Concerns

Long-distance shipping

There is great controversy today about shipping live cattle and other livestock to other countries for slaughter. This creates two problems: the stress of long-distance transport and the potential for poor slaughter facilities at the destination. In these situations, the trade is driven by customer preferences and economic factors. It may be possible to change customer preferences, but some of the economic factors will be difficult to overcome. A good example is the shipment of young Australian cattle to Indonesia for fattening and slaughter. Live cattle

Table 3.1. Animal welfare tradeoffs for electrical versus controlled atmosphere stunning of pigs and poultry.

Electrical	CO ₂ , LAPS ^a or other gas
Low purchase cost (both species)	High purchase cost (both species)
Unconsciousness is instantaneous (both species)	Unconsciousness is not instantaneous (both species)
Pre-slaughter handling is more stressful (both species)	Tradeoff in pigs and poultry is behaviour during anaesthesia induction must be balanced against the improved handling
Lower maintenance and operating cost (both species)	Pre-slaughter handling is less stressful (both species)
Requires more supervision of employee behaviour (both species)	High maintenance and operating cost (both species)
More blood spots in the meat of pigs	Requires less supervision of employee behaviour (both species)
High amperage electrical stunning causes more meat damage in broiler chickens	Requires careful monitoring of gas concentration or LAPS operation
	Meat damage varies with controlled atmosphere method (poultry)

^alow atmospheric pressure stunning

have the advantage of not requiring refrigeration in a country that has little infrastructure. Shipping refrigerated or frozen meat to countries such as Japan or Korea is economically viable because the customer is paying for a premium product. It is also easy to find a back haul, such as electronics, to fill the refrigerated shipping containers when they are returned. Customers buying premium meat products may also prefer to ship the meat by air.

The Indonesian situation has complex tradeoffs. Rural ranchers in Australia are engaging in sustainable production of cattle on pastures in the arid outback. Grazing animals are one of the best methods for raising food on their land. Shipping the cattle for final fattening in Indonesia increases the number of cattle that can be produced in a sustainable manner on the Australian outback. This land is too arid for growing crops. Grazing can be done with a favourable net carbon balance at moderate stocking rates (Bray *et al.*, 2014). Again, there is another tradeoff. If the system is pushed too hard by increasing stocking density on the pasture, the sustainability benefits may be lost. To make shipping refrigerated beef to Indonesia economically feasible would require finding a good back haul for the empty refrigerated containers. The most readily available back haul would be palm oil. This is really bad from an environmental standpoint. Rainforest is being destroyed for palm oil plantations. The best approach may be to ship the live cattle to Indonesia and have them sent to a modern slaughter house, run by Australian managers. This solution is not ideal for animal welfare, but it may be best from the standpoint of carbon footprint, sustainable agriculture and degradation of the environment. A reasonable level of animal welfare could be attained by enforcing rigorous standards for shipping and slaughter.

Tradeoffs on feed consumption

To improve animal welfare, some poultry growers are using slower-growing chickens. Use of the slower-growing strains will often cut death losses during rearing in half (Thornton, 2016). From a sustainability standpoint, the slowest-growing birds require much more feed. Up to 20% more feed may be required to produce the same amount of chicken meat (Thornton, 2016). This means that 20% more land would be required to grow the feed. A sensible compromise may be to use a slightly slower-growing bird and then breed to prevent problems such as

lameness. I have observed that the poultry industry is already doing this. Unfortunately, they are reluctant to publish their research on this topic.

Nutritional environmental tradeoffs: beta agonists

Recently there have been problems with broken legs and other bones during transport and handling at the slaughter plant. This is thought to be due to reducing minerals such as phosphorus in the ration to reduce phosphorus in the manure. Specimens sent to a diagnostic laboratory from pigs raised in the USA have shown that 19% of the animals had rickets, an old vitamin-deficiency disease (Canning *et al.*, 2017). This is due to reducing costs of the ration. Behavioural research indicates clearly that pigs should receive roughage for rooting and chewing (Van der Weerd *et al.*, 2008). Many producers are reluctant to feed roughage, because it increases the amount of manure. Again, there is a tradeoff of welfare versus sustainability issues related to manure.

Tradeoffs in Commercial versus Research Welfare Assessments

Animal welfare evaluation systems used in a commercial abattoir and in a research setting are different. To be effective, an assessment system for commercial use must be much simpler (Grandin, 2010). The reality is that auditors and managers have to be able to be trained in a day-and-a-half workshop. After the workshop, they have several shadow audits with an experienced auditor.

The trend in writing animal welfare guidelines is to use outcome measures that are animal-based instead of specifying exactly how a facility is designed (Wray *et al.*, 2003; Welfare Quality, 2009; Grandin, 2010; Velarde and Dalmau, 2012). Examples of outcome-based measurements are body condition score, lameness, bruises, panting score for heat stress, cleanliness of the animals, death loss, sickness, vocalization during handling, falling during handling and others. Grandin (2017) contained a review of welfare indicators that can be assessed at the abattoir. Producers, transporters and slaughter plant managers should track progress in reducing lameness and other problems by scoring these variables. On each numerically scored variable, cut-off points have to be determined for minimum acceptable levels. The cut-off points should be set where the best 25% of producers can

attain them (Grandin, 2010). The other producers will need to be given time to bring their practices up to the standard. How did I decide where the cut-off point should be? This cut-off point worked well in previous work on assessing abattoirs on stunning and handling (Grandin, 2010). I have been on many welfare committees for many different species of animals. Unfortunately, I observed problems where the worst producers got on the committees so that they could set acceptable levels of lameness way too low. This enabled the worst farms to pass the audit.

Tradeoffs and Equipment Design

There have been many cases where expensive, difficult-to-maintain pieces of equipment have been installed in a developing country. The local people did not have the skills or resources to maintain it. Some examples of equipment that is only suitable for technologically advanced areas are controlled atmosphere stunning systems with complex conveyors or hydraulic lifting floors in livestock trucks. If the people cannot maintain the equipment, it is useless. In these situations, equipment with fewer difficult-to-maintain mechanical parts is more appropriate.

The corral, stockyard and race systems shown in this book and in Grandin and Deesing (2008) can all be built by local people with easily available materials such as steel or concrete. They also have the advantage of being low maintenance and they do not require automated or mechanized parts. In many developing countries, there is a lack of loading ramps for loading and unloading animals on to farm trucks. Loading ramps can be easily built from either metal or concrete. Moving parts are not required.

Economic Factors Can Either Improve Welfare or Make it Worse

When producers have to pay for bruises, they work to greatly reduce them (Grandin, 1981). However, if losses are passed on to the next segment of the marketing chain with no financial accountability, bruises and damage to livestock are usually greater (Grandin, 2015). Several studies have shown that cattle and sheep that pass through auctions have more bruises compared with livestock sold directly to a slaughter plant (Cockram and Lee, 1991; McNally and Warriss, 1996). The payment method

for employees can also affect the quality of handling. Paying stock people based on the number of animals handled per hour may provide an incentive to handle animals roughly. Stock people should be paid based on the quality of handling by providing incentive pay for low levels of injuries or bruises.

How to Make Tradeoff Decisions

In my own work, to make decisions, I have used a combination of data collected during audits and my own observations from over 200 abattoirs in over 20 different countries. For example, how did I make the decision on the tradeoff between elimination of electric prods for pigs and elimination of shackling live birds and escape attempts from gas stunning systems? Escape movements are a well-defined behaviour that auditors and plant managers can easily observe. Everyone who cares about animal welfare can agree that escape attempts from the container are not acceptable. It is more difficult to make a definitive statement about which is worse: 15% of the pigs getting poked with an electrical prod, or four or five gasping movements before a pig falls over and loses posture in CO₂? This would require additional research. I also put management factors into my decisions. From my experience in slaughter plants, I have learned that supervising employees to keep electric prod use at low levels is more difficult than managing a group-handling CO₂ machine. To explain the tradeoff in simple terms: the CO₂ machine is expensive and more difficult to maintain, but day-to-day management of the people handling the pigs is easier. Electrical stunning systems are economical to buy and easy to maintain, but require much more supervision of the people handling and stunning the pigs.

Conclusions

Making ethical decisions on tradeoffs is sometimes difficult. There are tradeoffs between productivity and welfare and between sustainability and welfare. At what point has welfare been compromised? Welfare has been compromised if animals have higher death losses during transit, lameness or signs of heat stress. There are abusive practices that are always wrong and there is never a tradeoff. Numerical objective outcome measures should be used to evaluate welfare.

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4

Condition of Animals on Arrival at the Abattoir and Their Management During Lairage

MICHAEL COCKRAM*

Sir James Dunn Animal Welfare Centre, Atlantic Veterinary College, University of Prince Edward Island, Canada

Summary

Although most animals that arrive at an abattoir are in a reasonable state, i.e. they are fit, healthy and not suffering, some types of animals require immediate attention and additional care. They can arrive at an abattoir in poor condition for the following reasons.

- They were not fit for their journey to slaughter and should not have been loaded.
- They are compromised animals, in an impaired condition, at the end of their productive life and were culled and sent for slaughter because of their condition.
- They were injured during handling or during their journey or their health deteriorated during the journey.
- Their journey conditions or their management before and during transport were not satisfactory.

To reduce the numbers of animals that arrive at an abattoir in poor condition, guidance is discussed on how to:

- assess fitness for transport;
- undertake on-farm euthanasia for animals not fit for transport; and
- develop on-farm policies to avoid transporting animals in a deteriorated and compromised condition.

How lairage conditions and the management of animals in a lairage may or may not mitigate the condition of the animals on arrival and avoiding

deterioration of their welfare during lairage will be discussed. Resting behaviour and the importance of physical and social environmental factors in meeting the behavioural and physiological requirements of the animals while in a lairage are emphasized.

Learning Objectives

- Categories of animals that have compromised welfare.
- Guidance on assessing fitness for transport.
- Guidance on developing on-farm policies to avoid transporting unfit animals.
- Understand animal welfare issues in the lairage at the abattoir.
- Learn about food safety and hygiene procedures in the lairage.

Arrival of Animals in the Lairage, Initial Welfare Assessment and Ante-mortem Inspection

It is a complex logistical task to coordinate the arrival of animal loads in relation to their time of slaughter so that vehicles are not kept waiting to unload, there is sufficient space available in the lairage to receive the animals and the animals are not kept too long in the lairage before slaughter. Ideally, loads should be provided with a specific arrival time; however, there can be delays because of loading difficulties, traffic and poor weather conditions etc. (Ljungberg *et al.*, 2007; Grandin, 2017).

* Email: mcockram@upei.ca

Whenever possible, the lairage staff and, if necessary, the veterinarian and animal welfare officer should be informed when and ideally before a load arrives that contains animals that require additional care and attention. Documentation on the fitness of the animals before loading or information from the driver of potential welfare issues that arose during loading or during the journey should be communicated to the slaughter plant. The driver's report and the initial assessment of the load by lairage staff represent a critical control point for animal welfare. For example, the load might need to be given priority for unloading and the animals slaughtered as soon as possible. One or more animals might not be suitable for unloading and could require either assistance to unload (Warren *et al.*, 2010), slaughter/euthanasia on the vehicle or separation after unloading into an isolation pen. Animals that are weak, fatigued, severely lame or neonatal ('bobby' veal calves) will require careful handling. Where the journey to slaughter was long, or the conditions were problematic, some animals can arrive in a state of hunger, thirst, fatigue, stress or be thermally compromised. The animals should be observed on arrival, during unloading and entry into the lairage for signs of heat stress, injury and painful conditions. Their management in the lairage should either reduce the duration that they continue to experience any aversive states by slaughtering them as soon as possible, mitigate the severity of any suffering or provide resources that rapidly resolve these difficulties. It is also important that steps are taken to communicate the nature of any serious welfare issues found on arrival at the slaughter plant with relevant parties, such as the transporter, the farm of origin of the animals and possibly any intermediary stages, such as an auction market. A discussion and guidance on how to reduce the risk of reoccurrence of these welfare issues should be initiated and, where necessary, practices amended.

Ante-mortem inspection

Before the animals are taken to slaughter an ante-mortem inspection is conducted to assess whether each animal is suitable for human consumption and can proceed for slaughter. If the inspection identifies an issue, the animal can be declared unsuitable for human consumption, and if necessary killed in the lairage, moved to an isolation pen in the lairage and possibly slaughtered separately from other animals, e.g. at the end of the day's

slaughter. A veterinarian or inspector would normally observe each animal (except poultry) at rest and while moving. The inspection is intended to identify animals showing clinical signs of disease, especially those conditions that may not be readily identifiable post-mortem, such as neurological signs. If necessary, this inspection is followed by a full clinical examination (Food Standards Agency, 2018). Another important function of ante-mortem inspection is to identify whether an animal is experiencing a welfare issue and to obtain information that might be required to take any necessary action, such as follow-up procedures with the farm of origin. This is an important opportunity for welfare surveillance as it could be the first occasion when an animal is exposed to inspection by someone other than the producer (Lahti and Soini, 2014). Examples of the types of welfare issues considered by the inspector during their inspection include poor body condition, difference in body size in relation to other animals in a group, and injuries and overgrown hoofs (Lahti and Soini, 2014). Ante-mortem inspection of poultry in containers is difficult, and it might only be possible to observe a sample of the birds for mortality, overcrowding and some obvious clinical signs, such as panting, prostration and nervous signs. Documentation on flock health can also be inspected (Allain *et al.*, 2018).

Animals That Arrive at an Abattoir in Poor Condition

Some animals arrive for slaughter in an unfit condition because they were not fit before the journey and should never have been loaded. In most countries, this would be a contravention of legal regulations and/or industry and international standards (OIE, 2011). In other cases, animals arrive unfit because their health deteriorated during the journey. Unless an unforeseen and unusual event occurred during the journey, the arrival of an animal in an unfit condition suggests that it was not fit for the intended or anticipated journey. However, some animals may have had pathology that was not readily apparent before loading (Harris *et al.*, 2018) and they may not have had any obvious clinical signs of disease or injury for a competent stockman or transporter to recognize. In some situations, an animal could become injured during handling, loading or during their journey. Some animals that are not in good health or optimal condition are transported to slaughter in a compromised

Table 4.1. Description of terms used to categorize the condition of animals on arrival at a lairage.

Category of animal	Description
Unfit for transport	Shows signs of infirmity, illness, injury or of a condition that indicates that it could not have been transported without suffering
Compromised	Shows signs of infirmity, illness, injury or of a condition that indicates that it had a reduced capacity to withstand transportation
Non-ambulatory Injured	Unable to stand or move without assistance and unable to bear weight on two legs Presence of skin injury, bleeding wound, bone fracture, joint dislocation or damaged prolapse, or other external lesion
Severely lame Fatigued	Injured, crippled, or physically disabled with an abnormal gait and limp or walks with difficulty Non-injured with a temporary reduction in the ability or motivation to walk and with increased motivation to rest
Dead-on-arrival	Animal found dead in the vehicle before unloading and entry into the lairage or was dead in a container on arrival or after lairage

or impaired condition because they are culled at the end of their productive life. In this situation, those involved would have considered that their condition was not so poor as to make them unfit for transport under the conditions provided for the journey. The economic value of compromised animals as a source of food for human consumption would have outweighed any potential welfare concerns regarding their transportation. Transportation can, in some circumstances, represent significant challenges even for fit and healthy animals. These challenges are greater for animals that are weak, diseased or injured. These types of animals were likely to have been experiencing welfare issues, such as pain and sickness, before loading and in this condition, they were less able to cope with the additional challenges associated with transport (Cockram, 2019). Animals that are not in good health are more likely to become fatigued, injured, non-ambulatory or die during transport.

Although in many or most loads the prevalence is zero, surveys of animals at slaughter plants show that some animals, especially cull animals, can arrive in poor condition (González *et al.*, 2012). For example, Dahl-Pedersen *et al.* (2018b) assessed that 2% of the cull dairy cows that arrived at a Danish plant were severely lame. Many of the cull cows observed had become lame during the journey, or the severity of their lameness had increased during the journey. Unless there is strong regulatory enforcement or strict industry standards, some cull dairy and beef cows can arrive at slaughter plants in extremely poor condition. For example, they can be severely lame, extremely emaciated, have foot abnormalities, joint and jaw abscesses, swollen joints, mastitis, and rectal and vaginal prolapses

(Nicholson *et al.*, 2013; Harris *et al.*, 2017; Dahl-Pedersen *et al.*, 2018c). In the USA, Vogel *et al.* (2011) assessed that 23% of cull dairy cows sent to slaughter via a market were sick. Cull sows can have foot lesions, abscesses and ulcers, signs of major pathology, such as pneumonia and peritonitis, and low body condition (Cleveland-Nielsen *et al.*, 2004; Knauer *et al.*, 2007). Although they occur less often, metritis, mastitis, chronic arthritis, fractures or osteomyelitis may also be present (Cleveland-Nielsen *et al.*, 2004). In a survey of slaughter plants conducted in five countries, 0.2% of pigs were assessed as sick on arrival (Dalmau *et al.*, 2016). When Jacobs *et al.* (2017c) undertook a rigorous assessment of the fitness of broilers before transport to slaughter, the main issues that they found were lameness, emaciation and clinical signs of illness or injury.

If neonatal bobby-veal male dairy calves are sent for slaughter, they can arrive in an extremely vulnerable, dehydrated and exhausted condition and some may require euthanasia (Stafford *et al.*, 2001; Thomas and Jordaan, 2013). They are likely to experience difficulty walking and require very careful handling (Leary *et al.*, 2016). Lactating dairy cows with obvious udder distension should be slaughtered as soon as possible or milked (OIE, 2016).

Euthanasia

Euthanasia is required if an animal:

- arrives at the slaughter plant and cannot be unloaded from a vehicle, e.g. it is non-ambulatory;
- cannot be moved to the slaughter area for stunning and exsanguination;

- cannot be moved to the slaughter area for exsanguination after stunning outside the stunning area without a risk of it regaining consciousness before it can be exsanguinated; or
- is suffering (see Chapter 2 for signs of pain) and immediate slaughter is not possible or appropriate.

The difference between euthanasia and slaughter in this context is that an animal that has passed ante-mortem inspection, been stunned and then killed by exsanguination or cardiac arrest can potentially enter the human food chain, whereas an animal that has been euthanized cannot, either because of the secondary method of killing, e.g. pithing following captive bolt stunning (see Chapter 2), or because it did not pass ante-mortem inspection. See later section for appropriate methods of euthanasia.

Dead-on-arrival and Mortality During Lairage

A small proportion of the animals transported to slaughter are dead-on-arrival (DOA) at the plant and others die during lairage (Knowles *et al.*, 1994; Fitzgerald *et al.*, 2009; Warren *et al.*, 2010). If DOAs are identified, it might indicate that the animals that survived the journey require extra care and attention (Ritter *et al.*, 2009). The frequency of DOAs is highest in poultry (Petracci *et al.*, 2006; Di Martino *et al.*, 2017; Cockram and Dulal, 2018). Broilers can die during handling and transport from heat or cold stress, trauma and disease (e.g. heart conditions, ascites and infectious disease) (Nijdam *et al.*, 2006; Kittelsen *et al.*, 2015). Mortality can occur in pigs (Ritter *et al.*, 2009) and the mortality risk is dependent on the genotype (Murray and Johnson, 1998; Grandin, 2001; Fabrega *et al.*, 2002) and the risk of heat stress (Averos *et al.*, 2008). In a survey of slaughter plants conducted in five countries, 0.09% of pigs were dead-on-arrival, and 0.008% were found dead in the lairage (Dalmau *et al.*, 2016). Especially for poultry, the recording and regular assessment of mortality rates is important: (i) to identify whether the mortality rate of a particular load is greater than normal and requires specific investigation; (ii) to examine flock/herd health, driver and transport records to identify risk factors that could be manipulated to reduce future deaths; and (iii) to provide benchmarking statistics to compare the plant with industry norms and to identify significant

variations in performance between transporters, farms of origin, etc. In many countries, any livestock DOAs or a high percentage of poultry DOAs is likely to attract the attention of regulatory authorities, who will conduct their own investigation.

Non-ambulatory Animals

Although some animals can become non-ambulatory during transport (González *et al.*, 2012), many non-ambulatory animals that arrive at slaughter plants were either non-ambulatory or otherwise not fit for transport before loading (Stull *et al.*, 2007; Frimpong *et al.*, 2014). It is not possible to load non-ambulatory cattle without causing extensive pain and injury (Grandin, 2001). On-farm euthanasia should be considered for cows that have been non-ambulatory for more than 24 h (Green *et al.*, 2008). Most non-ambulatory cattle are dairy cows, but some beef cows can become non-ambulatory during transport (Stull *et al.*, 2007; Goldhawk *et al.*, 2015; Harris *et al.*, 2017). They are unable to stand and walk because they are injured (e.g. calving-related, slips and falls), weak (e.g. emaciated), or sick (e.g. metabolic and toxic conditions) (Stull *et al.*, 2007). Lameness, fractures, severe arthritis and various neurological conditions can increase the risk of pigs becoming non-ambulatory during a journey (Sutherland *et al.*, 2008). In one study, 0.24% of pigs that arrived at a slaughter plant were non-ambulatory and not injured; 0.08% were non-ambulatory and injured (Correa *et al.*, 2013). Non-injured, non-ambulatory pigs can have signs of metabolic acidosis and greater concentrations of serum cortisol and catecholamines than ambulatory pigs (Anderson *et al.*, 2002). This suggests that some pigs become non-ambulatory following the development of stress and fatigue during the journey to slaughter (Ritter *et al.*, 2009).

In many countries, non-ambulatory animals must not be dragged off the vehicle or lifted by the limbs, tail, neck or ears. Non-ambulatory cattle that arrive at a slaughter plant should be euthanized on the vehicle, i.e. stunned and then killed using a secondary method, such as pithing or exsanguination. In some countries, non-ambulatory pigs and sheep can be moved off the vehicle and into the slaughter plant on sleds, mats, specialized carts or mechanized equipment that supports the full length and weight of the animal. If a non-ambulatory animal impedes the unloading of ambulatory animals, it should be removed or euthanized before

continuing with unloading (Leary *et al.*, 2016; Grandin, 2017).

Injured Animals

Some animals arrive with an injury that was caused during handling and transportation or was present before loading. These injuries can range from skin lacerations, bruising (Strappini *et al.*, 2009), trauma to the udder (Goldhawk *et al.*, 2015) and trauma to existing lesions, such as a hernia or damaged foot, to bone fractures and dislocations (Bueno *et al.*, 2013). Broilers and spent laying hens are susceptible to injury during handling and transport. Jacobs *et al.* (2017b) found that 1.9% of broilers examined in a lairage had wing fractures and 0.14% leg fractures. Cull sows can arrive with a range of injuries, such as skin and vulval wounds and shoulder ulcers (Fogsgaard *et al.*, 2018). Some cull animals are more susceptible to injury because they are weak and likely to acquire skin wounds and bruising during handling and transport (Strappini *et al.*, 2013; Goldhawk *et al.*, 2015; Dahl-Pedersen *et al.*, 2018b) or because their bones are fragile and are more likely to fracture (Newberry *et al.*, 1999; Grandin, 2001). If an animal is in pain, it should be killed as soon as possible (Chirico *et al.*, 2017). If an injured animal can be unloaded, it should either go immediately to slaughter or, if this is not possible, moved to a pen near the unloading area where it can be separated from other animals and provided with additional care. Extra care needs to be taken when moving injured animals, as movement of or pressure on a painful wound or area of inflammation causes additional pain.

Sick and Lame Animals

Some producers send animals to slaughter in a sick or diseased condition because they wish to obtain the maximum financial return from an animal that can no longer be treated economically or is unlikely to recover its productive performance. However, there is a financial risk that the animal may not survive transportation, or may be euthanized en route or on arrival at the slaughter plant; in some countries, the producer and transporter are at risk of regulatory enforcement penalties for transporting an animal that may not have been fit for transportation; and there is a high risk that part or the whole carcass will be condemned as unfit for human consumption (Jackowiak *et al.*, 2006;

White and Moore, 2009; Rezac *et al.*, 2014). There are extra costs to a slaughter plant in dealing with diseased animals. The line speed may have to be reduced to allow for careful inspection and extra trimming; and due to the risk of contamination, some animals may need to be slaughtered at the end of the normal period.

Severe lameness can be observed in some animals that arrive at a slaughter plant (Warren *et al.*, 2010). This is a serious welfare issue, as most lameness is caused by pain. Animals with painful foot lesions are more reluctant to bear weight on their feet than healthy animals, and pressure on a lesion causes additional pain (Dyer *et al.*, 2007; Flower *et al.*, 2008). Gait scoring systems are available to categorize the severity of alterations in gait (Angell *et al.*, 2015; Edwards-Callaway *et al.*, 2017; Fogsgaard *et al.*, 2018). However, in a Danish study, there was only moderate agreement between veterinarians and farmers and between veterinarians and livestock drivers on the assessment of lameness in cull dairy cows (Dahl-Pedersen *et al.*, 2018a). In a survey of slaughter plants conducted in five countries, 0.4% of the pigs were assessed as severely lame on arrival (Dalmau *et al.*, 2016). Harris *et al.* (2017) assessed cattle that arrived at slaughter plants in the USA and observed that 0.3% of cull dairy cows and 0.1% of cull beef cows were extremely reluctant to move even when encouraged, and 4.7% of cull dairy cows and 2.3% of cull beef cows were obviously lame. In a survey in Denmark of cull dairy cows selected by farmers for transport to slaughter, more than 1% were evaluated as not fit for transport because they were severely lame (i.e. obviously lame in one or more legs, and unable, unwilling, or very reluctant to bear weight on the affected leg) and 31% were classified as lame (Dahl-Pedersen *et al.*, 2018c).

Guidance on Assessing Fitness for Transport

The number of animals that arrive at slaughter plants in poor condition would be reduced if there was a more effective assessment of the fitness of animals before they are loaded on the journey to be sent to slaughter. In many countries, there are detailed legal regulations on the criteria for the fitness of animals for transport. In these countries, if an unfit animal arrives at a slaughter plant, there are procedures for the collection of evidence and the investigation of suspected breaches of welfare

legislation with the possibility of penalties imposed on the producer and transporter (European Commission, 2016). The Office International des Epizooties chapter on the transport of animals by land (OIE, 2011) contains the following standards on the fitness of animals under section (c), which states that animals that are unfit to travel include, but may not be limited to:

- i) those that are sick, injured, weak, disabled or fatigued;
- ii) those that are unable to stand unaided and bear weight on each leg;
- iii) those that are blind in both eyes;
- iv) those that cannot be moved without causing them additional suffering;
- v) newborn with an unhealed navel;
- vi) pregnant animals which would be in the final 10% of their gestation period at the planned time of unloading;
- vii) females travelling without young which have given birth within the previous 48 h;
- viii) those whose body condition would result in poor welfare because of the expected climatic conditions.

Guidelines and decision trees that include examples of the types of clinical conditions that would make an animal unfit for transport are available. Some examples for cattle, pigs, sheep and poultry are Eurogroup for Animals *et al.* (2012, 2015), National Farm Animal Care Council (2013) and Poultry Industry Council (2017). However, different stakeholders have different views on the criteria that would make an animal unfit for transport (Grandin, 2016; Herskin *et al.*, 2017; Dahl-Pedersen *et al.*, 2018a). There is a potential conflict between the avoidance of the risk of suffering arising from a decision not to transport an animal that is not fit for transport and the financial loss associated with on-farm euthanasia compared with the potential return to a producer from transporting the animal for slaughter so that it can be sold for human consumption (Magalhães-Sant'Ana *et al.*, 2017). There are often very limited options for on-farm slaughter with the transport of the carcass to a slaughter plant, but where this option is available, it is likely to reduce some of the dilemmas associated with decisions on fitness for transport and economics (Magalhães-Sant'Ana *et al.*, 2017; Koralesky and Fraser, 2018). Greater dissemination of information on fitness for transport issues, guidance and training on the criteria for fitness for

transport to producers, veterinarians and transporters, and enforcement of legal regulations or industry standards has been advocated (European Commission, 2016). A major difficulty with the enforcement of regulations on the fitness of animals is differentiating between conditions that were present and readily identifiable before loading and those that occurred during the journey. Ante-mortem and post-mortem inspection, together with an appreciation of the underlying pathological mechanisms and the age of lesions, can assist in resolving this issue (European Commission, 2016). A proportion of the animals sent for slaughter have pathological conditions that were only identified post-mortem, but were present before transportation and may not have been readily apparent before loading (Visser *et al.*, 1992; Cockram, 2019). Consideration of the pathophysiological implications of ill-health and injury on an animal's response to the potential physical and physiological challenges that can occur during transportation readily identifies the potential for suffering that can occur if compromised animals are transported (Cockram, 2019). It is therefore important that animals with identifiable conditions that make them unfit for transport are not sent for slaughter.

Guidance for On-farm Euthanasia of Animals Not Fit for Transport

For animals that are either experiencing suffering that cannot be mitigated, are not fit for transport, have no reasonable prospect of economic recovery or are not fit for human consumption, on-farm euthanasia is the preferred option (Fig. 4.1). Producers should be encouraged to develop a suitable on-farm euthanasia plan that is part of their health and welfare plan developed in consultation with the herd/flock veterinarian (Turner and Doonan, 2010). This should include clinical endpoints, decision trees, training of staff and appropriate methods of euthanasia. Developing clear agreed-upon criteria for euthanasia and effective training can assist those required to make difficult decisions on euthanasia and then undertake euthanasia (Turner and Doonan, 2010; McGee *et al.*, 2016). Shearer and Reynolds (2011) provide examples of conditions that often result in on-farm euthanasia. Examples of the reasons for euthanasia of dairy cows are mastitis/udder problems, lameness/locomotor disorders, calving problems, accidents and metabolic/digestive disorders (Thomsen

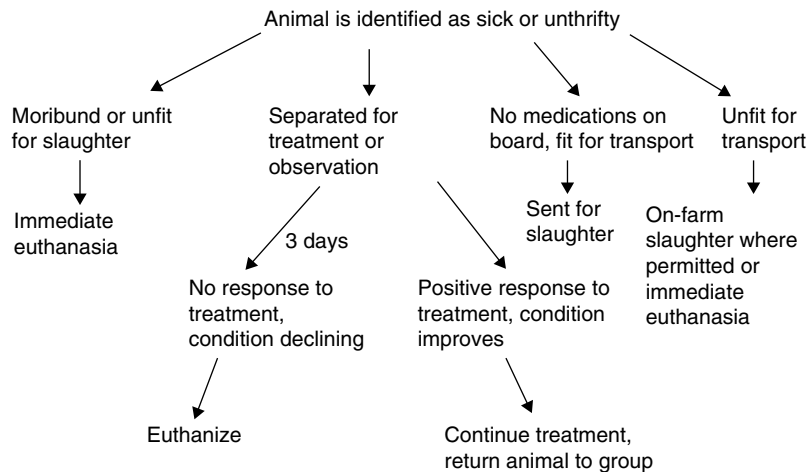


Fig. 4.1. Example of an algorithm used for developing an on-farm euthanasia protocol. (Source: Turner and Doonan, 2010, with permission.)

and Sørensen, 2009; McConnel *et al.*, 2010; Fusi *et al.*, 2017). Cull sows are euthanized because of traumatic injuries, fractures or paralysis; prolapse/dystocia; lameness; abscesses; and poor body condition (Engblom *et al.*, 2007, 2008; Jensen *et al.*, 2010).

In many countries, the percentage of animals euthanized on-farm has increased due to lowered thresholds for euthanasia to avoid animal suffering, to reduce treatment costs and to avoid penalties arising from the enforcement of animal welfare regulations (Thomsen and Sørensen, 2008). However, most producers will only undertake euthanasia in extreme circumstances. They are reluctant to undertake on-farm euthanasia because of the costs involved in undertaking euthanasia, the cost for disposal of the body and the loss of carcass value (Langford and Stott, 2012; Edwards-Callaway *et al.*, 2019). Another issue is the reluctance of a caretaker to kill an animal for which they have provided daily care (Rault *et al.*, 2017; Campler *et al.*, 2018). On some units, it may also be difficult to find a competent person and suitable equipment to undertake euthanasia (European Commission, 2016).

There are various options for on-farm euthanasia (Humane Slaughter Association, 2016) and guidelines are available (e.g. Leary *et al.*, 2016; National Pork Board, 2016; Poultry Industry Council, 2016; Shearer, 2018), but in some locations unacceptable methods that do not minimize suffering or cause instantaneous loss of consciousness and a reliable death are undertaken (Dalla

Costa *et al.*, 2019). Animals can be killed by a veterinarian using a lethal intravenous dose of an anaesthetic drug, but there are then restrictions on carcass disposal. A firearm that fires a free bullet or a shotgun that shoots multiple projectiles from close range into the brain of the animal can be an effective way of undertaking on-farm euthanasia. A rifle can be used to kill sheep, pigs and small cattle, but correct shot placement is important (Humane Slaughter Association, 2016). Captive bolt stunning, followed by bleeding or pithing, can be used where a free bullet is impractical for safety reasons. Although some animals will be killed by captive bolt stunning, if a secondary step is not used there is a risk that the animal will return to consciousness (Appelt and Sperry, 2007). Some types of captive bolt equipment have been designed specifically for euthanasia, but they do not always kill the animal after the first shot, and either a secondary step or multiple shots may be required (Derscheid *et al.*, 2016; Gilliam *et al.*, 2018). In one survey in the USA, 96% of the dairy cows that were euthanized were euthanized on-farm, 78% using a firearm, 7% with a captive bolt and 7% with a euthanasia solution (Aly *et al.*, 2014).

On-farm euthanasia of poultry can be required because of accidental injury or disease. Methods include the use of a percussive bolt, manual or mechanical cervical dislocation by stretching or crushing, and blunt trauma, followed by exsanguination (Bader *et al.*, 2014; Cors *et al.*, 2015).

Where the condition of spent laying hens is poor (fragile bones, feather loss and poor body condition), there is no market for their carcasses and no plant within a reasonable distance that slaughters laying hens, on-farm euthanasia is undertaken. This avoids the welfare risks associated with pain from injury during handling and exposure to cold environments during transport (Newberry *et al.*, 1999; Richards *et al.*, 2012). The options for whole-flock euthanasia are the use of carbon dioxide in mobile containers or inside the barn, use of in-barn anoxic foam, handheld electrical stunners and maceration (McKeegan *et al.*, 2013; Berg *et al.*, 2014).

Guidance on Developing On-farm Policies to Avoid Transporting Animals in a Deteriorated and Compromised Condition

Improved on-farm procedures for decision making concerning if and when cull animals should be sent for slaughter would reduce the number of animals that arrive at abattoirs in poor condition (Grandin, 2001). Animals need to be culled before they become weak, debilitated and not fit for transport (Stojkov *et al.*, 2018). For poultry, adopting a rigorous culling programme during rearing will reduce the risk of mortality during transport (Jacobs *et al.*, 2017a). Culling procedures should form part of a written farm health and welfare plan developed in consultation with the unit's veterinarian that includes protocols for early identification of animals that need to be treated, culled and sent for slaughter or euthanized on-farm (Doonan *et al.*, 2014). An effective health plan, regular health monitoring and veterinary advice on preventive measures, biosecurity and treatment protocols should improve the health and fitness of the animals and reduce the number of animals on a farm that need to be culled prematurely (LeBlanc *et al.*, 2006; Scott *et al.*, 2007). Regular on-farm health assessments using gait scoring (Schlageter-Tello *et al.*, 2014) and body condition scoring (Roche *et al.*, 2004; Bewley *et al.*, 2008) are useful to identify animals suitable for culling before they become unfit for transport (Grandin, 2018). Thin animals are more likely to be injured or bruised during transport, have an increased risk of becoming non-ambulatory (Grandin, 2001) and can be more susceptible to cold conditions (Verbeek *et al.*, 2012). Grandin (2001) suggested that improved genetic selection and breeding practices and the selection of transporters who provide

optimal standards for the transportation of animals would improve the condition of animals on arrival at slaughter plants. Ritter *et al.* (2006) showed that avoiding overcrowding during a journey reduced the risk of pigs becoming non-ambulatory. In broilers, the methods used for on-farm catching and handling (Cockram and Dulal, 2018) have a major influence on the prevalence of bone fractures, especially wing fractures (Kittelsen *et al.*, 2015; Jacobs *et al.*, 2017b).

Breeding animals are culled, i.e. removed from the herd or flock, for several reasons, including low production, poor breeding performance and health problems (Bascom and Young, 1998). There are many factors that affect culling decisions, including the age, stage of lactation, production, health status, behaviour, reproductive status and the producer's attitude to risk and uncertainty (Beaudeau *et al.*, 2000). Economic factors such as the economic return from the output of the animal, e.g. milk or calf/piglet price, the price that can be obtained for cull animals at slaughter and the price and availability of replacement animals are major factors that can affect a culling decision (Bascom and Young, 1998; Beaudeau *et al.*, 2000). If culling is 'voluntary,' i.e. planned, producers have the options of selling their animal immediately, waiting for increased prices or feeding the animal before auction. Depending on the type and condition of the animal, the options for cull animals that leave the farm can include sending the animal directly to slaughter for human consumption at either a large slaughter plant or a local abattoir, or to an auction market for sale for slaughter or further fattening.

The reason for culling can affect the fitness of the animals for transport. Animals that are culled 'involuntarily' because they are sick, lame, weak or injured are more likely to suffer during transport and can represent an economic loss to the producer (Chiumia *et al.*, 2013). Health issues such as udder and mastitis problems, lameness, injury and disease are major causes for culling of dairy cows (Hadley *et al.*, 2006). A proportion of dairy cows that arrive at slaughter plants are lame, in poor body condition and have mastitis (Nicholson *et al.*, 2013). The timing of culling for dairy cows because of lameness can depend on the type of lesions (e.g. foot rot and sole ulcers), the stage of lactation and pregnancy status (Booth *et al.*, 2004).

An important aspect of the culling decision is the marketing route chosen for the animals. Cull cows and sows may be sent for slaughter via auction

markets, as this has the potential to maximize financial returns (Blair and Lowe, 2019; Edwards-Callaway *et al.*, 2019). These animals may be collected from the farm by a dealer who then forms a batch of animals to send to a market or to a specialist slaughter plant that could be a considerable distance from the farm (Stojkov *et al.*, 2018). Sending a compromised cull animal to an auction market can increase the journey duration and expose the animal to extra handling, novel environments, restricted availability of feed and water, and may provide reduced opportunities for rest and more opportunity for any existing health conditions to deteriorate.

In the absence of legal regulations and their effective enforcement, a producer might decide to risk transporting a compromised animal to attempt to obtain the maximum financial return and avoid the costs of undertaking on-farm euthanasia and subsequent carcass disposal. However, there are risks of mortality, animal suffering, failure to pass meat inspection and poor public perception of these practices (Edwards-Callaway *et al.*, 2019). Even in situations where cull cows that are unfit for sale or further transport are prohibited from sale, a large proportion of cull cows sold at a market can be in poor body condition and lame. Although these conditions can reduce their value, the economic returns from selling these animals at a market can be high (Moorman *et al.*, 2018).

Although not available in many locations, on-farm slaughter is an option that allows an animal to be slaughtered for human consumption without having to be transported alive to another location. This could be achieved using a mobile slaughter plant, or the animal could be slaughtered (using normal stunning and bleeding procedures) on the farm and then the carcass transported to a slaughter plant for post-mortem inspection (Koralesky and Fraser, 2018; Stojkov *et al.*, 2018). In a study in Italy of on-farm mortality, 30% of the dairy cows that died on-farm were euthanized, and 25% were slaughtered on-farm and the carcasses sent to a slaughter plant (Fusi *et al.*, 2017). On-farm slaughter is suitable for animals that pass ante-mortem inspection and are likely to pass post-mortem meat inspection, for example animals that have had an accident, are non-ambulatory or have locomotion problems due to trauma, arthritis or foot lesions (Hirvonen *et al.*, 1997; Cullinan *et al.*, 2010, 2012; Fusi *et al.*, 2017; Koralesky and Fraser, 2018).

The ability of slaughter plants to exchange information within the meat production chain is influenced by the closeness of the relationship between a slaughter plant and individual producers or producer groups. This can be affected by the social, economic and regulatory environment (Deimel and Theuvsen, 2011), whether there are intermediary stages in the supply of animals to the plant, such as an auction market, and by the ownership of a slaughter plant and the production units that supply the animals for slaughter. If positive relationships can be established (Devitt *et al.*, 2016) there are animal health and welfare and economic advantages to both parties in the communication of best-practice guidelines and feedback to producers on the ante-mortem and post-mortem condition of the animals received for slaughter (Willeberg *et al.*, 1984; Harley *et al.*, 2012). This can be achieved through direct contact and industry bodies. See Chapter 16 for further details on welfare issues that can be identified at slaughter.

Lairage

After arrival at a slaughter plant, animals that are not taken directly to slaughter are placed in a lairage (sometimes referred to as stockyards, holding pens, holding yards or holding barns). The original meaning of a lair or lairage is a place where animals can lie down and rest, but the lairage serves several potential functions. The main purpose is to act as a holding area to provide a reservoir of animals that are readily available to be taken for slaughter so that the speed of the slaughter line can be maintained without waiting for the arrival of animals. A lairage is preferable to leaving animals on a vehicle waiting to be unloaded just in time for slaughter. A lairage can provide more effective ventilation and facilities for resting, feeding and watering. It is often stated, that for welfare reasons, stressed and fatigued animals require lairage to rest and recover from handling and transportation. However, if animals are taken directly to slaughter shortly after unloading, they have little time to experience any further negative consequences arising from transportation, and it can be argued that this is preferable to keeping them in a lairage where they could continue to experience a negative affective state. This is especially the case where the lairage does not provide an optimal environment and causes further stress. The one welfare argument for providing animals with an opportunity to rest and recover from transportation

is where animals have become so excited or agitated that they are difficult to handle and move to the point of slaughter and might also require additional restraint to ensure effective stunning (Chirico *et al.*, 2017). Placing wet cattle and sheep in a lairage can provide an opportunity for them to dry off before slaughter and thereby reduce the risk of contamination of the meat during dressing procedures. Depending on the genotype and the pre-slaughter treatment, there is some evidence that a period of lairage can improve the meat quality of some pigs. A lairage also serves as a critical control point for food safety and animal welfare, as it provides an area for ante-mortem inspection of the animals (Jalakas *et al.*, 2014). The condition of the animals and the facilities in the lairage should be checked regularly during the day by the lairage staff and at least daily by the slaughter plant management and a veterinarian. The principles affecting the design of lairage pens and handling in the lairage are covered in Chapters 6 and 12. Lairage pens should be of secure construction, without risk of injury to the animals, provide protection from predation and be arranged to permit inspection of animals at any time, with corridors between pens or overhead walkways, and facilities to remove sick or injured animals (Chirico *et al.*, 2017).

There should be an emergency plan to deal with contingencies that could affect the welfare of the animals in the lairage and those that are en route to the lairage. Examples of potential events that require planning are an extended plant stoppage, disruption of services to the lairage (such as electricity and water), fire, extreme weather conditions and strict biosecurity procedures following a notifiable disease outbreak. The plan should be kept in a visible location and should be reviewed at least annually. For animals that are en route to the plant that cannot be returned to their farm of origin, there should be a designated place where animals can be unloaded and provided with adequate care (Leary *et al.*, 2016; Grandin, 2017). If there is a risk of a delay in unloading animals after a vehicle has arrived at the lairage, the installation and use of a bank of fans with water misters just outside of the lairage can be effective in reducing the risk of heat stress while the vehicle is stationary (Pereira *et al.*, 2018).

Duration in Lairage

There are several considerations that affect the duration that animals are held in the lairage

(Warriss, 2003). Practical issues such as the timing of deliveries in relation to the timing and speed of slaughter can increase the duration that animals need to be held in the lairage. Limitation on the capacity of a lairage can reduce the duration that animals can be kept before slaughter. Some animals are slaughtered without spending any time in the lairage, but many animals spend several hours and some may be kept overnight (Small *et al.*, 2007). There are animal welfare, meat quality and food safety issues that can influence this duration. Ideas on the optimal duration that animals need to be kept in a lairage have evolved. Practices vary between species and countries (e.g. see Gallo and Huertas, 2016), and can depend on factors such as the physical environmental conditions during transportation and lairage, duration of fasting and genotype.

A prolonged period in a lairage or holding barn is a major risk factor for broiler mortality (Nijdam *et al.*, 2004; Knezacek *et al.*, 2010; Chauvin *et al.*, 2011; Caffrey *et al.*, 2017). Providing appropriate ventilation and thermal conditions can, in some circumstances, be challenging. Some of the deaths during lairage can also be a delayed consequence of injury during catching and loading, others the result of problems experienced during the journey, e.g. hypothermia or hyperthermia (Caffrey *et al.*, 2017), and some might occur due to a combination of factors, including the duration of fasting and chronic disease (Cockram and Dulal, 2018).

Animal Welfare

In most situations, from an animal welfare perspective that considers the affective state of animals, the duration that animals are present in a lairage should be kept to a minimum. There are several reasons for keeping this duration short. Some animals arrive in a lairage with a welfare issue such as a painful injury that arose during transport or was present on the farm. Early slaughter of these animals will reduce the duration of any suffering. For various reasons discussed in this chapter and Chapter 2, it is difficult to provide an optimal environment for animals in a lairage. Some environmental aspects can be harmful and the welfare of an animal can deteriorate with time in the lairage. Some animals in the lairage are kept in unstable social groups and interactions between animals such as fighting or mounting can cause stress and injury. The severity of these injuries can increase

with duration in the lairage. With this reasoning, unless recovery is necessary to facilitate handling or stunning (Warriss, 2003), lairage is never beneficial for animal welfare.

Some confusion can nevertheless arise over whether lairage is beneficial for animal welfare, due to differences in how animal welfare is understood. The above reasoning and the discussion in Chapter 2 are based on the consideration that animal welfare is entirely dependent on what an animal feels. However, due to difficulties in assessing the affective state of an animal, some approaches to animal welfare assessment use disturbances to biological functioning or to the fitness of an animal as the criteria on which to assess animal welfare (Fraser *et al.*, 1997; Fraser, 2003). If this approach to animal welfare is taken, it is possible to come to a different conclusion over optimal lairage durations. After transportation, it is not uncommon for several aspects of an animal's physiology to be affected, such as raised body temperature, increased plasma concentrations of cortisol, increased plasma creatine kinase activity, increased mobilization of metabolites associated with fasting and sometimes biochemical changes associated with dehydration. In favourable lairage conditions, these variables can return to normal with time in the lairage (Averos *et al.*, 2007). The biological functioning approach would consider that the welfare of the animals would be improved if they were given the opportunity to recover from these physiological disturbances, e.g. provided with sufficient time for plasma cortisol concentrations to return to normal (Warriss *et al.*, 1992; Perez *et al.*, 2002; Liste *et al.*, 2011). Using this approach, an optimal lairage duration would be based on how long these physiological variables take to return to 'normal' or baseline values. However, if the animals are stressed, do not rest, do not drink readily or do not have sufficient access to feed, their physiological variables may not stabilize in the lairage and their condition can deteriorate rather than improve.

Meat Quality

The evidence that animals require a short period in a lairage for improved meat quality is complex, variable between species and genotype within species, and dependent on other aspects of pre-slaughter management. However, there is convincing evidence that some aspects of meat quality can deteriorate with increased time in the lairage. With prolonged

lairage, there can be reduced carcass weight and an increased risk that the animals will acquire a zoonotic infection (Warriss, 2003). Keeping some pigs for a short period in a lairage compared with immediate slaughtering upon arrival can in some circumstances be beneficial for meat quality. If the handling and transport of pigs have been stressful, resting them in a lairage can allow them to recover from some of this stress, and this can in some circumstances improve some aspects of meat quality (Warriss, 2003). Stress-susceptible pigs need more time to recover from transportation than stress-resistant pigs (De Smet *et al.*, 1996). However, if halothane-negative pigs are transported for a relatively short duration, in conditions that do not cause heat stress, and are kept in small and stable social groups, slaughtering without a period of lairage may not necessarily result in poor meat quality (Aaslyng and Barton Gade, 2001).

Some pigs that are slaughtered on arrival can have a higher temperature and a faster post-mortem muscle pH decline than those kept in lairage for 1–2 h (Terlouw *et al.*, 2008). A short period of lairage for 1–2 h before slaughter can in some circumstances improve meat colour and reduce the risk of pale, soft and exudative (PSE) meat (Dokmanović *et al.*, 2014). However, long lairage periods allow more time for fighting between the pigs, the duration of fasting is longer, the amount of skin damage is increased, and muscle glycogen concentration is reduced, thereby increasing the risk of dark, firm and dry (DFD) meat (Guàrdia *et al.*, 2009; Faucitano, 2010; Čobanović *et al.*, 2016). After fasted pigs are placed in a lairage pen without access to feed, they can be active, investigating the pen, drinking water and mounting. This activity tends to decrease with time, but fighting can increase to maximum intensity after about 1 h. Fighting can be more intense and skin damage more severe with increased duration of fasting before loading (Brown *et al.*, 1999b). Pigs that have been fighting are likely to be more stressed, have increased metabolic activity, higher body temperature and increased muscle lactate concentration and if slaughtered in this condition could have reduced meat quality (Faucitano, 2010). Other studies have shown that meat from pigs slaughtered immediately after transport had more desirable sensory properties (juiciness, tenderness, palatability) than those lairaged for 24 h (Śmiecińska *et al.*, 2011). A meta-analysis of 13 studies on pigs with mixed social grouping, held in

lairage for between 0.25 and 24 h, failed to identify a significant effect of lairage duration on muscle $\text{pH}_{4,5}$, muscle reflectance or drip loss. The only significant effect of lairage duration was a potentially negative effect on meat quality, namely an increase in pH_u in semimembranosus muscle (Salmi *et al.*, 2012). However, fasting duration and transport duration also affected some aspects of meat quality; therefore, the effects of lairage duration on meat quality are also likely to be influenced by these factors.

In most cases, beef quality is not significantly improved by the time that cattle spend in lairage (Wythes *et al.*, 1988; Ferguson *et al.*, 2007). Del Campo *et al.* (2010) found a lower muscle $\text{pH}_{2,4}$ after steers that had been transported for 4 h had been lairaged for 15 h compared with 3 h. However, prolonged lairage, e.g. 24 h, can increase live weight loss and increase the risk of DFD meat (Gallo *et al.*, 2003). In young bulls, if lairage duration is kept to a minimum, meat quality is improved and the risks of DFD meat and bruising are reduced. Ideally, young bulls should be slaughtered as soon as possible after arrival. After long journeys lasting 1–2 days, the effect of lairaging young bulls with access to feed and water for longer than 2 days compared with 1–2 days on muscle pH_u is inconsistent and likely depends on the behavioural activity in the group (Liotta *et al.*, 2007; Teke *et al.*, 2014).

Availability of Water

There are no meat quality or food safety issues that preclude the provision of drinking water to animals in the lairage (Wythes *et al.*, 1985). After animals have been transported on long journeys, most animals in a group may need to drink on arrival in the lairage (Wythes *et al.*, 1980). For example, Jarvis *et al.* (1996) observed that 60% of cattle drank within the first 3 h of arrival in a lairage. Transportation can cause dehydration in livestock, but if offered ready access to water in the lairage the signs of dehydration are rapidly reduced (Gortel *et al.*, 1992; Averos *et al.*, 2007; Mota-Rojas *et al.*, 2009). Pigs transported for 8–24 h regained 0.8% of their weight due to drinking during an 8 h lairage period (Becerril-Herrera *et al.*, 2007). The volume of water drunk by pigs will depend on factors such as the temperature, the journey duration, duration of fasting and the type of feed previously offered (Saucier *et al.*, 2007; Goumon *et al.*, 2013).

Facilities for the provision of drinking water should be available in each lairage pen. Nipple drinkers, automatic troughs or buckets can be provided, but it is important to check that the animals can drink from the type of drinker provided and that it is placed at an appropriate height to allow the size of animal in the pen to drink. Water sources should be checked regularly to ensure that they are clean, in working order and used by the animals. It is good practice to provide more than one source of drinking water per pen and sufficient sources to allow easy access, e.g. one drinker per six cattle and one drinker per 12 pigs (Chirico *et al.*, 2017). However, in practice, the number of animals per drinker frequently exceeds this ideal (Dalmau *et al.*, 2009, 2016).

If animals are kept in a lairage for a prolonged period with access to water, not all animals will necessarily drink. After 15–28 h without water, Jongman *et al.* (2008) observed that only 80% of the sheep drank water during a 24 h lairage. Some animals may not drink enough to recover from dehydration associated with transportation, or they may not drink sufficient water to prevent progressive dehydration while kept in a lairage (Liu *et al.*, 2012). If animals do not have access to water, they will become progressively dehydrated, especially in warm environments (Jacob *et al.*, 2006; Pearce *et al.*, 2008; Vanderhasselt *et al.*, 2013). It is difficult to provide water to birds in containers and they should be slaughtered as soon as possible after arrival (Chirico *et al.*, 2017).

Availability of Feed

As discussed in Chapter 2, it is normal practice to fast animals before slaughter. If the animals are only present in the lairage for a few hours, it has traditionally not been considered necessary to provide feed. However, on arrival in the lairage, some animals will already have experienced a period of fasting on the farm before loading, a second period without feed during transportation and will then experience a third period without feed in the lairage. Regulations and guidelines provide a limit on the duration without feed in the lairage, e.g. 12 h (OIE, 2016), but most guidelines do not take into consideration the length of fasting before arrival in the lairage. The guidelines also suggest that if animals are not slaughtered within 12 h, they should be provided with suitable feed on arrival and at subsequent intervals appropriate to the species.

The lairage should provide facilities for feeding. Where feed troughs are provided, they should be sufficient in number and feeding space to allow adequate access for all animals to feed (OIE, 2016).

Hungry animals may be less likely to rest in a lairage. Pigs that have been fasted for a prolonged period can show increased activity and fighting that can adversely affect carcass and meat quality (Dalla Costa *et al.*, 2018). Access to feed and water in the lairage for several hours allows the animals to regain some of the weight lost during transport, reduces the requirement to mobilize body energy reserves in response to an energy deficit and allows them to recover some of their energy reserves (Brown *et al.*, 1999a; Cockram *et al.*, 1999; Knowles *et al.*, 1999). When offered feed in a lairage, most animals will eat it; for example, Jarvis *et al.* (1996) observed that 93% of cattle ate hay within the first 3 h in a lairage pen. After very long journeys, if feed and water are available for several days, most but not all sheep will eat, most sheep will recover from the effects of fasting, and muscle pH_u will improve (Shorthose, 1977). Pre-ruminant suckling lambs are more susceptible than ruminants to periods of food and water deprivation. As there is no improvement in meat quality with lairage, it is preferable to slaughter suckling lambs as soon as possible after arrival (Díaz *et al.*, 2014).

Thermal Environment in the Lairage

Lairages can differ in the degree of protection provided to the animals from adverse weather conditions. Lairages can range from an environmentally controlled building, a naturally ventilated building, or a covered pen, to an uncovered pen or field (Small *et al.*, 2007). In all situations, shelter must be provided to protect the animals from excessive wind and precipitation and to offer shade. The optimal temperature within a lairage is difficult to define, as several factors interact to influence the effective environmental temperature experienced by the animals. The thermal requirements of animals vary greatly, depending on factors such as body size, coat and tissue insulation, length of fasting, floor type and the availability of bedding, and there are differences between species in the mechanisms that they have for evaporative heat loss.

Young animals, pigs, poultry, shorn sheep, cull cattle and those in poor body condition, with a wet coat, exposed to draughts, fasted for prolonged periods and kept in pens without bedding, have

increased susceptibility to cold conditions and wind-chill (Grandin, 2017). In pigs, shivering and huddling are signs of cold stress that can sometimes be observed during lairage (Dalmau *et al.*, 2009).

Heat stress in livestock

Livestock and poultry are susceptible to heat stress. Signs of heat stress in livestock are an increased respiration rate, decreased feed intake and increased drinking. This can be followed by panting, open-mouth breathing, salivation and, if severe, reduced coordination, trembling and recumbency (Huynh *et al.*, 2005; Al-Dawood, 2017; Polsky and von Keyserlingk, 2017). The severity of heat stress can be identified using numerical scoring systems (e.g. Gaughan *et al.*, 2008). Some animals can be hyperthermic on arrival, especially after long journeys in raised temperature and humidity (Miranda-de la Lama *et al.*, 2018). On arrival in the lairage, some pigs can show panting, open-mouth breathing and hyperventilation, especially during warmer conditions, e.g. $\geq 17^{\circ}\text{C}$ (Mota-Rojas *et al.*, 2006; Kephart *et al.*, 2010; Dalmau *et al.*, 2016) and some cattle can be observed to be sweating on arrival (Warren *et al.*, 2010).

Heat stress occurs when the metabolic heat produced by the animal is greater than its capacity to lose this heat to the surrounding environment. The exchange of heat between an animal and its environment is affected by the air temperature, humidity, air movement and radiant heat. Heat is lost to the environment through non-evaporative heat transfer to the air and surrounding surfaces by convection, conduction and thermal radiation exchange. The surface of an animal can gain heat from solar radiation; therefore, a roof or shade can provide protection from solar radiation. When an animal is lying down, heat exchange can occur through conduction to the floor. The type of floor surface and whether bedding is provided are especially important for the thermal conditions of pigs. In warm conditions, the pigs may lie down to increase body heat conduction to the floor, whereas in cooler conditions they stand and huddle (Fraqueza *et al.*, 1998). Convective heat loss from air movement can remove surface heat, and this cooling is increased if the body surface is wet and water is evaporated from the surface. An air velocity of 0.2–0.5 m/s can remove the boundary layer of air insulation surrounding an animal (Berman, 2019) and faster speeds, e.g. 3 m/s, can disrupt air contained within

the coat insulation and provide cooling (Collier and Gebremedhin, 2015).

Evaporative heat loss through the evaporation of water from the body surfaces, especially from the respiratory tract, is important as air temperature rises. This mode of heat transfer is influenced by the water vapour pressure difference between inhaled and exhaled air. The risk of heat stress increases when there is a combination of high temperatures and high humidity, and temperature–humidity index charts have been developed to indicate the risk of heat stress (Sullivan and Mader, 2018). If pigs are kept in hot and humid conditions in a lairage for several hours, meat quality can be affected (Santos *et al.*, 1997) and the risk of mortality is increased (Vitali *et al.*, 2014). This risk is reduced if the stocking density is kept low and water sprinklers are used for cooling (Vitali *et al.*, 2014).

Water sprays and fans are used in hot conditions to assist cooling. If the humidity is not high, the evaporation of water from surfaces surrounding an animal can also cool the air. Recommendations for misting or wetting pigs are to avoid excess humidity by using a large droplet spray rather than a fine mist, allow pigs time to dry in an area with air movement before wetting them again, and avoid showering in cold conditions, as this can cause shivering and huddling (Weeding *et al.*, 1993; Knowles *et al.*, 1998; Dalmau *et al.*, 2016; Grandin, 2017).

Heat and cold stress in poultry

Poultry are susceptible to both heat stress and cold stress during lairage. Prolonged exposure to thermal environmental extremes can result in mortality from either hyperthermia or hypothermia (Knezacek *et al.*, 2010; Caffrey *et al.*, 2017). A poultry lairage or holding barn should provide adequate shade and insulation from solar radiation (Ritz *et al.*, 2005). Combinations of high temperature and high humidity pose a high risk of mortality (Tao and Xin, 2003a). The main way in which birds lose excessive heat is through the evaporation of water from the respiratory tract and through the skin (Genç and Portier, 2005). As the air temperature rises, the respiration rate increases and, eventually, panting occurs (Gleeson, 1985). High humidity impairs the ability of the birds to lose heat via respiratory evaporative cooling (Quinn *et al.*, 1998; Genç and Portier, 2005). In hot and humid conditions, the survival time for broilers

before they collapse from heat exhaustion and die depends on the temperature rise within the container, the duration of exposure and the thermal regulatory ability of individual birds (Cockram and Dulal, 2018). The handling system and the lairage design can have a major influence on the thermal environment experienced by poultry. If the birds remain in crates on the trailer, the provision of sufficient ventilation to all of the birds in the load can be challenging (Cockram and Dulal, 2018). The temperature within the crates can rise above the external temperature and the body temperature of the birds can increase (Hunter *et al.*, 1998; Warriss *et al.*, 1999). Poultry kept in containers in a lairage are not provided with drinking water and will not have had access to water during catching, loading and the journey to slaughter. Birds that are exposed to high temperatures without access to water for prolonged periods are at an increased risk of dehydration and hyperthermia (Zhou *et al.*, 1999). Bird behaviour should be monitored for signs of heat stress (panting and birds turning towards the side of modules to obtain fresh air) (Chirico *et al.*, 2017). Jacobs *et al.* (2017a) reported a significant association between the percentage of birds panting during lairage and the risk of mortality. Air movement can reduce the risk of hyperthermia in broilers exposed to hot conditions (Hamrita and Conway, 2017). In hot conditions, an evaporative cooling system in addition to fan ventilation can reduce mortality in holding barns (Shackelford *et al.*, 1984). In warm weather, water sprays can provide evaporative cooling and wetting of the birds (Tao and Xin, 2003b), but can increase the relative humidity.

A poultry lairage also has to protect the birds from wind, precipitation and extremely cold temperatures. The lower critical temperature for broilers at the time of slaughter is about 24°C (Meltzer, 1983) and at temperatures below this the birds must reduce their heat loss and/or increase heat production. When broilers are exposed to cold temperatures, they can respond by placing their head and feet under their body, huddling, ptiloerection, vasoconstriction, shivering and increasing their metabolic rate (Strawford *et al.*, 2011). In a cold climate, the lairage needs temperature-controlled mechanical ventilation combined with heating. In some countries when poultry are transported during the winter months, the external temperature can be extremely low and during transport the birds (especially those near air inlets without external

protection from cold air and water) are susceptible to hypothermia, frostbite and freezing (Hunter *et al.*, 1999; Strawford *et al.*, 2011). In cold conditions, broilers are at an increased risk of death the longer that they are kept in the lairage (Knezacek *et al.*, 2010; Caffrey *et al.*, 2017) and meat quality can be reduced (Bianchi *et al.*, 2006; Dadgar *et al.*, 2011, 2012).

Ventilation in the Lairage

Effective ventilation in the lairage is important to remove waste gases and avoid the build-up of metabolic heat and moisture and to replace these with fresh air distributed throughout the lairage. The ventilation system should be designed and when necessary adjusted to provide suitable temperatures for the types of animals in the lairage (Wathes *et al.*, 1983). The ability of the ventilation system to remove waste products from the air and avoid poor air quality is dependent on the number of animals present in the air space and on their stocking density. In temperate climates, many live-stock lairages are naturally ventilated and these are suitable for adult ruminants. The air movement is achieved by utilizing prevailing wind and thermal buoyancy. For natural ventilation to be effective the lairage has to be sited away from other buildings and obstructions that would block the prevailing wind. Thermal buoyancy will only work if the external temperature is lower than the internal temperature and there is a height difference between the outlets and the inlets. If a naturally ventilated building is too wide or understocked, air flow will not be sufficient in all parts of the building. A common design consists of inlets around the wall comprising space boarding and a raised roof ridge outlet. Ventilation can be adjusted by opening and closing doors and windows (Small *et al.*, 2007; Mondaca, 2019).

In environments where the temperatures can be extreme, natural ventilation cannot be relied upon always to provide suitable conditions and adjustable mechanical ventilation is required. Temperature-controlled mechanical or fan ventilation with ducting is required for pig and poultry lairages to avoid the risk of heat and cold stress. This may need to be combined with air conditioning and heating systems. The ventilation system should function with minimum noise, avoid draughts and always provide sufficient air movement to extract stale air and replace it with fresh air. The ventilation

rate can be increased by increasing the inlet area and the speed and number of fans in use. Extractor fans can be used to remove humidity and metabolic heat (Chirico *et al.*, 2017). Mechanical ventilation systems require regular maintenance of equipment, and air quality should be monitored. When necessary, temperature, humidity and ammonia concentration should be measured, displayed and recorded. If there is a smell of ammonia, this indicates that there is insufficient minimum ventilation (Weeks, 2008). If mechanical ventilation is used, an alarm and emergency back-up facilities are required in case the system breaks down. The alarm system should be able to function even if there is a power failure and an emergency generator should be provided. There should be a contingency plan and an alternative (natural) means of providing ventilation must be available if the mechanical ventilation fails (Chirico *et al.*, 2017).

Ventilation for poultry

In poultry lairages effective ventilation inside and between containers can reduce the mortality risk (Cockram *et al.*, 2019). Ventilation can only be effectively achieved by unloading the containers from the vehicle and stacking them at appropriate locations in the lairage with a gap between them (Hunter *et al.*, 1998). However, stacking containers concentrates metabolic heat and moisture production, reduces the surface area for cooling and reduces the airflow around each container. Ventilation within poultry containers is difficult, as there is little space above each layer of birds and, especially at high stocking density, side ventilation openings in the containers may be partially obstructed by the birds (Warriss *et al.*, 2005). In both summer and winter, the temperature and humidity within a container are likely to rise during lairage and this can cause an increase in body temperature (Hunter *et al.*, 1998; Quinn *et al.*, 1998; Warriss *et al.*, 1999). If the containers remain on the vehicle, banks of fans are required to provide side ventilation. In hot conditions, the load can also be placed under showers for several minutes after arrival (Freitas *et al.*, 2016) and misting systems can be used to cool poultry (Quinn *et al.*, 1998). However, if the humidity is high, the misting system will add humidity to the air and reduce the ability of the birds to lose heat by panting (Chirico *et al.*, 2017).

Social Behaviour That Can Cause Stress or Injuries

The design and management of a lairage needs to consider the social behaviour of the animals. Different species should be penned separately. Ideally, animals should be kept in the same social groups that they were in when they were reared on the farm and then transported to slaughter. Mixing groups of either pigs or cattle together from different sources is likely to cause them to fight to establish a new social order. Animals likely to injure another animal should either be slaughtered as soon as possible or a fractious animal should be penned separately. Aggressive animals with horns or tusks capable of injuring other animals, breeding bulls and boars should be penned separately. Attention should also be given to ensuring that only animals of similar size are placed in the same pen. Sexual behaviour between entire boars or young bulls and between female cattle in oestrus can cause mounting, injury and poor meat quality (Kenny and Tarrant, 1988).

Either because insufficient numbers of pigs of the required weight range can be obtained from the same pen or because the size of the pens available during transport and lairage are often different from those used on farm, it can be difficult to avoid mixing different social groups of pigs (Guise and Penny, 1989; Grandin, 1990). If pigs are mixed, fighting can occur before loading, during transport and in lairage (Terlouw *et al.*, 2008; D'Eath *et al.*, 2010). If pigs are mixed, fighting during lairage can be reduced if the group size is kept low (Rabaste *et al.*, 2007), overcrowding is avoided, the period of fasting is not prolonged (Terlouw *et al.*, 2008), the pigs are kept in the dark and, if fed, sufficient feed is offered to reduce aggression at feeding (Barnett *et al.*, 1994). Most of the fighting occurs within the first hour after arrival in the lairage (Moss, 1978). Temporarily dividing large lairage pens to keep pigs in small groups can reduce aggression (Faucitano, 2001). Some pigs are more aggressive than others, and unless these pigs are removed, they can cause increased fighting and skin damage (D'Eath *et al.*, 2010). Mixing pigs can decrease muscle pH_{45} , and increase skin damage, muscle pH_u and the risk of DFD pork (Guise and Penny, 1989; Karlsson and Lundstrom, 1992; D'Souza *et al.*, 1999). However, if pigs are not mixed, fighting is not common and most pigs lie down within 1–2 h of arrival (Moss, 1978).

Social interactions, such as mounting and aggression, between young bulls are such a problem that keeping them in groups in a lairage should be avoided. If lairage is necessary, mixing should be avoided, the duration should be kept as short as possible, and mounting and aggressive behaviour reduced by keeping the animals in lowered light intensity or by providing an overhead barrier or electric grid (Kenny and Tarrant, 1987; Bartos *et al.*, 1988). If young bulls from different social groups are penned together, there is vigorous agonistic activity and mounting (Warriss *et al.*, 1984). This exercise increases muscle pH_{24} and causes DFD meat (Franc *et al.*, 1988; Bartos *et al.*, 1993). There is increased bruising, greater plasma creatine kinase activity and greater plasma cortisol concentration (Kenny and Tarrant, 1987).

Space Requirements in the Lairage

The design capacity of a lairage is affected by the number and type of animals required to be present at any one time, the number and size of pens required for holding animals while the slaughter line is operational, the space required to provide facilities for resting, drinking and feeding overnight, and the capacity of the ventilation system (Chirico *et al.*, 2017). If the stocking density exceeds the capacity of the ventilation system to remove metabolic heat, the animals could experience heat stress (Weeks, 2008). It is good practice to set and label each pen with maximum and minimum stocking rates and provide a temporary label indicating the date and time of arrival of the animals in the pen (Chirico *et al.*, 2017). The stocking density refers to the number or live weight of animals within a specified floor space, e.g. number of animals/m² or kg/m². Space allowance refers to the floor space provided per animal, e.g. m²/animal. Space allowance ranges are specified depending on the weight and type of animal.

For livestock, the amount of space that an animal requires in a lairage depends to some extent on the length of time that it will remain there, as this affects what behaviour they need to perform (Petherick, 2007). For lairage lasting only a few minutes, an animal might require little more space than it occupies. For normal lairage lasting for more than a few minutes, each animal will require sufficient space to be able to rest, stand up, lie down, turn around, drink and thermoregulate. If held overnight they would normally require additional space to access feed. An estimation of the amount

Table 4.2. Minimal recommended space allowances for animals in lairages (adapted from Chirico *et al.*, 2017).

Type of animal	Weight (kg)	Presence of horns	Duration in lairage (h)	Space allowance (m ² /animal)
Calves	200		< 3	0.7–0.8
			> 3	0.9–1
Cattle	550		< 3	1.4–1.5
			> 3	1.8–1.9
	700		< 3	1.6–1.7
			> 3	2.0–2.2
			< 150	≥ 1.5
			150–220	≥ 1.7
> 220		Without horns	≥ 1.8	
		With horns	≥ 2	
Piglets	25			≥ 2.3
Sows				0.14
Adult pigs other than sow or boar	115		< 12	> 1
			> 12	≥ 0.5
Lambs				0.65
Ewes	45–60			≥ 0.25
	60–90			1.1–1.2
Rams				1.2–1.4
				1.5–2.0

of space that an animal will occupy can be approximated from its size and shape using the equation:

$$\text{surface area (m}^2\text{)} = k W^{2/3}$$

where W is the weight of the animal (kg), and k is a constant (Petherick, 2007). The estimate for this constant varies between 0.019 if sufficient space is required for just sternal recumbency or standing and 0.047 if sufficient space is allocated for lateral recumbency. The linear space (m) required for feeding and drinking from a trough can be estimated from length = $0.064 W^{0.33}$. However, this length will be affected by factors such as the competition for feed or water (Petherick, 2007). Table 4.2 gives minimal recommended space allowances.

Rest and Holding Time in the Lairage

Although it has been traditional practice to provide a period of rest before slaughter, lairages may not always provide an ideal environment for animals to rest. After arrival in a novel environment, animals can take several days before they adopt a normal sleeping pattern (Ruckebusch, 1975). Livestock can rest when lying down with their head raised, but for sleep they adopt a relaxed posture with reduced muscle tone and with their head resting (Merrick and Scharp, 1971). Their sleep is polyphasic in that

they sleep in short periods rather than in one long period each 24 h (Ruckebusch, 1972; Ternman *et al.*, 2012). In a quiet environment, ruminants and pigs spend a large proportion of the day lying down (Ruckebusch, 1972). Before they sleep, they pass through a state of drowsiness that is characterized by a lack of behavioural activity and a low threshold of arousal (Ruckebusch, 1975; Campbell and Tobler, 1984). During this state, their rest can easily be disturbed by activity in the lairage (Tobler *et al.*, 1991). Most lying behaviour tends to occur during the evening and night when there is minimal human activity, with many animals standing up when human activity starts in the morning. To avoid disturbance of rest, it is preferable to avoid moving groups between pens (Jarvis *et al.*, 1996). The lighting in a lairage should be uniform and diffuse with sufficient intensity to enable inspection, but during the night the lighting should be dimmed to facilitate rest (Chirico *et al.*, 2017). Although they remain awake for long periods during the night, livestock sleep more during the night than during the day. When there is less activity during the day, they can also have some bouts of sleeping (Ruckebusch, 1975; Robert and Dallaire, 1986; Tobler *et al.*, 1991). Blue lighting is preferable for poultry (Adamczuk *et al.*, 2014). Poultry can rest while standing or sitting in a crouching posture

with the neck withdrawn, tail lowered and sometimes with the wings drooping. Their posture is similar for sleeping, but their head is tucked into the feathers above the wingbase or behind the wing (Blokhuis, 1984).

How quickly animals start to lie down and for how long is likely to depend on factors such as the availability of feed, the novelty of the lairage environment, their degree of fatigue, disturbance from other animals, noise and human activity, the space provided, time spent drinking and the presence of bedding or the type of floor surface (Cockram, 1990, 1991; Kim *et al.*, 1994; Jarvis and Cockram, 1995; Lebreton *et al.*, 2006; Barton Gade, 2008; Jongman *et al.*, 2008; Torrey *et al.*, 2013). Some animals lie down immediately after arrival in a lairage, but many take several hours to lie down, with the amount of lying increasing with increased duration in the lairage.

If the animals are kept in the lairage for longer than a few hours, a comfortable floor surface with low thermal conductivity should be provided to facilitate rest (Gordon and Cockram, 1995; Færevik *et al.*, 2005). This can be achieved by providing bedding, such as straw or sometimes wood shavings (Small *et al.*, 2007), or a soft surface such as rubber slats or mats. Where bedding is provided, it should be maintained in a condition that minimizes food safety risks from infection or surface contamination (Small *et al.*, 2007). If animals are kept overnight, a solid, dry lying area should be provided.

Lairages can be noisier than many of the on-farm environments where the animals were reared (e.g. between 76 and 110 dB) (Talling *et al.*, 1998; Weeks *et al.*, 2009) and this can disturb the ability of animals to rest and can contribute to the stress experienced during lairage (Chloupek *et al.*, 2009; Vermeulen *et al.*, 2015). Livestock can respond to higher sound frequencies than humans (humans 20–20,000 Hz, cattle 25–35,000 Hz and pigs 42–40,500 Hz) (Weeks *et al.*, 2009). The hearing range of broilers is 60–11,950 Hz (Hou *et al.*, 1973).

There are several potential sources of noise in the lairage:

- vocalization of animals and people;
- slaughter and shackling equipment;
- movement of animals between and in and out of pens;
- opening and closing of metal gates;
- ventilation fans; and
- high-pressure water hoses (Talling *et al.*, 1996, 1998; Weeks *et al.*, 2009; Chirico *et al.*, 2017).

Lairages tend to be quieter overnight when there is less activity than during the day (Weeks *et al.*, 2009). Lairages should be designed and materials selected to minimize noise, such as the use of rubber baffles on doors and gates. However, due to the requirement to keep the lairage clean, surfaces in the lairage are hard and amplify sound. Separation of noisy activities, e.g. vehicle washing, away from the lairage is beneficial (Chirico *et al.*, 2017).

Food Safety and Hygiene Procedures in the Lairage

The management of the lairage is influenced by food safety protocols to reduce the risk of contamination of the meat with bacteria such as *Escherichia coli* O157, salmonella and campylobacter. For example, there is a physical separation between the lairage and the ‘clean’ slaughter area of the plant to avoid direct movement of people, live animals and equipment between these areas. As livestock and poultry can be carriers of zoonotic bacteria, such as salmonella in their faeces, and these bacteria can be passed between groups in the lairage, cleaning and disinfection procedures are undertaken in the lairage to reduce surface contamination (Schmidt *et al.*, 2004; Buncic and Sofos, 2012; Mannion *et al.*, 2012; De Busser *et al.*, 2013). This requirement means that surfaces should be easy to clean and made of hard materials, such as concrete and metal (Small *et al.*, 2003). Roughened, grooved or smooth concrete, and concrete or metal slats are common types of floor surface used in lairages (Small *et al.*, 2007). In pig lairages, salmonella contamination is lower where a slatted floor is used compared with a solid floor (Hurd *et al.*, 2005). Cleaning and disinfection practices and the frequency of use of pressure washing or steam-cleaning vary between lairages (Small *et al.*, 2007). To reduce bacterial contamination between groups, pens should be left to dry after cleaning and disinfection (Walia *et al.*, 2017). Several lairage management practices are designed to reduce the risk of carcass contamination. Reducing the time spent in the lairage reduces the risk of the spread of infections between animals in the lairage. Whenever possible, animals are fasted in the lairage to limit defecation and coat contamination and the risk of spillage of gut contents during dressing procedures, but offering hay to cattle can reduce the risk of coat contamination with *Escherichia coli* O157 (Mather

et al., 2007, 2008). Hygiene practices that involve the removal of bedding between batches can restrict the use of bedding. However, the provision of bedding and providing time for wet and dirty coats to dry is sometimes used to improve the cleanliness of animals before slaughter. Alternatively, dirty animals might be slaughtered separately, the hair may be clipped, or the animals cleaned on arrival in a water bath or shower (Byrne *et al.*, 2007; McCleery *et al.*, 2008).

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5

The Basics of Bruising in Cattle – What, When and How

LILY N. EDWARDS-CALLAWAY^{1*} AND HELEN C. KLINE²

¹*Department of Animal Science, Colorado State University, USA;* ²*JBS Swift, Tolleson, Arizona, USA*

Summary

The welfare and economics of bruising have been a topic of discussion within the cattle industry over the past several years. Beginning in the early 1990s, the National Cattlemen's Beef Association implemented what is now called the National Beef Quality Audit to benchmark quality attributes of beef, bruising being one of the carcass defects measured. With these audits, the US cattle industry has been able to track the occurrence and subsequent economic impacts of bruising in the beef industry. During pre-slaughter transport and management, cattle are exposed to numerous events that can increase the risk of bruising such as multiple handling events, other animals, and various handling facilities and animal caretakers. Researchers and industry professionals can use the attributes of bruises, such as size, shape, pattern and color, to begin to understand where bruises are occurring within the supply chain. It is beneficial to couple post-mortem visual bruise assessment with ante-mortem assessment of handling in order to garner a more complete understanding of an animal's experience and subsequent bruise status. Incorporating visual bruise assessment into in-plant quality assurance programmes may be an effective way of raising awareness about bruising and its impacts on both quality and well-being. Even though this chapter is about cattle, most of the principles will also apply to sheep, bison, deer, goats or water buffalo.

Learning Objectives

- Bruising is a carcass defect caused by injury to the muscle that has economic and animal well-being implications.

- Bruises are not visible on the hides of live cattle. They must be assessed after hide removal during processing.
- Bruise characteristics such as location, size, colour and shape can provide clues as to how that bruise may have occurred.
- Coupling ante-mortem handling observations with post-mortem bruising assessment can be an effective method of understanding where bruises come from.
- Bruise monitoring programmes in the abattoir can help reduce bruise prevalence by increasing awareness.

Introduction

Bruising is something we all can relate to. We have grown up acquiring bruises on our legs from playing hard on the playground at school recesses, to being proud of a very large bruise we may have acquired participating in an exciting extreme sporting event, to lamenting over the bruises that happened after a mountain biking accident, or just being clumsy. Bruises are visible, everyone gets them, they are colourful (and the colour changes) and they come with a story. These everyday stories are often fond or embarrassing moments and we either remember exactly how the bruises were acquired or have no idea where they came from.

Unfortunately, there are also bruises that come from traumatic events, those associated with abuse, violence and crime. In these instances, it is often critical to understand what caused the bruise and when it occurred. The stories associated with these bruises are tragic and sometimes the victim cannot

* Email: Lily.Edwards-Callaway@colostate.edu

provide an explanation of events. Due to the high importance of understanding bruising in these contexts, there is a substantial body of research in the area of human forensics as it relates to bruising (Davis, 1998; DiMaio and DiMaio, 2001; Hughes *et al.*, 2004b). This information has been critical to human forensics but has also been beneficial in our understanding of bruising in livestock species. Forensic science has provided a platform of knowledge for many of the studies performed in animals to gain clarity on bruise characteristics, specifically bruise age.

Out of Sight, Out of Mind?

In humans, bruises are most likely visible at some point; if a bruise is deep it may take a few days to be visible on the skin surface and, depending on where the bruise is located, it may be covered by clothing. We notice other people's bruises, potentially enquire about them, and based on the visual clues often speculate about their origin. In many animals, bruises are not visible; thick hides and fur coats cover any bruises that an animal may have (pigs may be the exception when considering livestock). The fact that often we cannot see a bruise on an animal (livestock and pets included) sometimes diminishes the recognition that a particular, likely negative, event has resulted in a bruise and how painful that bruise could be. When bruises are out of sight, they are often out of mind and sometimes not even considered an 'injury'. This is not unique to livestock. A news article describing a 2007 Tour de France collision in which a rider collided with a dog on the racecourse (at race speed) comes to mind. After describing the significant crash in which the rider crashed into the dog's hind area at full speed, the reporter indicated that the dog 'was unhurt by the battering and clambered to its feet wagging its tail' but the rider had some 'cuts and bruises' (Robertson, 2007). It is likely that the crash would have caused some bruise formation on the dog, but the bruises were not visible and therefore were not considered.

The only way to see bruises in cattle is during post-mortem processing when the hides have been removed from the animal at the slaughter facility. Similar to criminal investigations, professionals in the livestock industry take the post-mortem bruising information and work backwards through the process to understand where the bruise came from and determine methods to prevent bruises in the

future. Bruises are certainly visible on the processing floor at slaughter plants and the prevalence has spurred significant research and monitoring during pre-slaughter activities to understand where the bruises are coming from. Although general awareness has been raised about the welfare implications of bruising based on what is found post-mortem (Henderson, 2016; Grandin, 2018; Kline, 2018), at the moment when traumatic events that have the potential to cause bruising occur, there is still some lack of consideration for the impact on animal well-being. For example, when we watch cattle unload from a truck and see jamming at the exit to the trailer, we do not necessarily consider that a bruise may be a consequence. The damage/trauma is not immediately visible and therefore not fully considered.

The Welfare and Economics of Bruising in the Cattle Industry

There are numerous reasons that professionals within the cattle industry should be concerned about bruising, two of the primary reasons being the impacts that bruising has on animal well-being and the economic impact of carcass bruising. The welfare implications of bruising are multifaceted. The most obvious impact that bruises have on animal well-being is that they are painful. Consider a bruise you have had in the past. The event that caused the bruise likely caused pain (potentially not if it was a very small bruise) and, depending on the size and severity of the bruise, there was likely tenderness associated with the injury post development. Simply, bruises are painful. Additionally, consider the event that led to the formation of a bruise on the animal. An event that is forceful enough to cause a bruise is likely to be traumatic for the animal, due not only to the discomfort the bruise caused, and will cause, but also from the fear response that the event may have triggered. Although the majority of bruises seen in cattle are minimal, i.e. small (prevalence to be discussed in later sections), some animals do have severe bruises post-mortem. Observing these types of bruises post-mortem makes one question what happened to that animal that caused such significant trauma. With this questioning also comes a feeling of compassion when contemplating what that animal felt while the trauma-causing event was occurring.

It is necessary to note that not all handling events will cause bruising and not all events that cause

bruising will cause severe bruises; likewise, not all handling events trigger fear and distress (most probably do not if low-stress handling is practised). It is important, though, to understand that these events can cause fear and distress, so that as we work with animals we should consider the implications of our behaviour, our approaches and our facilities. These trauma-causing events are not always caused by humans directly but since we are the stewards of livestock within our production systems, we do have a responsibility to try to prevent events like this from occurring, no matter the cause.

Bruised meat must not be used for human consumption

Additional consequences of bruising in livestock are the economic implications. Bruising is a carcass defect causing significant carcass damage. In slaughter facilities inspected by the US Department of Agriculture (USDA), bruises must be removed from the carcass during processing and this trimmed material is either rendered or discarded (CFR, 2019). In addition to the yield loss from trim, depending on the location and severity of the bruise, there is often an economic loss from devalued cuts, i.e. not an entire cut is lost but if a portion of a cut is removed the value will be reduced. Cattle industry stakeholders have estimated that bruising is currently costing the industry millions of dollars annually (Henderson, 2016; Lee *et al.*, 2017). In the 1994 National Non-fed Beef Quality Audit (NBQA), the first of many audits to be conducted by the National Cattlemen's Beef Association (NCBA) benchmarking a multitude of quality defects in beef, bruising included, it was calculated that US\$11.47 were lost per beef carcass due to bruising (National Cattlemen's Beef Association, 1994). Additionally, in the 1999 National Market Cow and Bull Beef Quality Audit, bruising was identified as the sixth leading cause of whole-carcass condemnation at the slaughter facility (Roeber *et al.*, 2001). Although reductions in bruise prevalence have been made since the inception of these benchmarking audits (Eastwood *et al.*, 2017; Harris *et al.*, 2017), the 2016 NBQA estimated that bruises still account for US\$3.41 per animal because of lost opportunity in carcass value within the beef industry (National Cattlemen's Beef Association, 2017).

Secondary to the carcass loss but also important are the reductions in slaughter plant efficiency associated with bruise removal. Depending on the

prevalence and the severity of carcass bruising, sometimes processing speeds (chain speed) at the slaughter facilities are reduced to manage additional time needed to trim off bruises. Additional employees may be needed to assist with the amount of trimming required on groups of carcasses with a high rate of bruising. To the authors' knowledge, there is not a published value on this cost but, in conversations with industry partners, it is evident that any reduction in line speed (efficiency) at a processing facility has a financial implication and therefore is not preferred.

Prevalence: how big is the problem?

As indicated, the NBQAs have been documenting bruise prevalence via visual assessment in the US cattle industry at slaughter since the early 1990s. The most recent NBQA data collected in 2016 on market steers/heifers, cows and bulls reported a bruise prevalence of 38.8%, 64.1% and 42.9%, respectively (Eastwood *et al.*, 2017; Harris *et al.*, 2017). Although the percentage of minimal bruises observed has increased in market cows, the percentage of major, critical and extreme bruises has decreased over the past 20 years. Eastwood *et al.* (2017) compared the 2016 NBQA bruise prevalence with prior audit years, demonstrating an increase in the percentage of market cows with no carcass bruises present, potentially a testament to the attention and importance that has been given to bruising in market cows in recent years. Harris *et al.* (2017) reported approximately a 15% increase in fed cattle that were bruised in addition to an increased percentage of fed cattle with multiple bruises in the 2016 NBQA as compared with the 2011 NBQA. Perhaps as cattle increase in size, the industry will need to adjust facilities (as generally handling facilities have remained static) to accommodate this change, in order to reduce carcass bruising (Harris *et al.*, 2017). Bruising will vary between facilities but the NBQAs provide a good reference point for comparison year over year. Wigham *et al.* (2018) provided a summary of bruise prevalence found in research studies globally, indicating a range of 37.5–97% bruising across studies.

'Iceberg Effect': bruises may not be visible on the carcass surface

In a recent bruising study assessing the actual trimmed bruise weight after visual bruise assessment in

multiple slaughter facilities, it was found that a considerable number of carcasses scored as not having a bruise were in fact trimmed for bruising (Kline, 2018). Kline (2018) found that nearly 75% of carcasses did not have visible bruising. Of those, 41.7% had bruising trimmed off. The plant employees were able to identify clues on the carcass surface that there were deeper bruises not evaluated as a 'bruise' during visual assessment. The authors have named this observation the 'Iceberg Effect' since these deep-tissue bruises on cattle are not readily visible on the surface but penetrate deep into the muscle. This is a new finding that should be explored in future studies to understand identification of these bruises.

Bruising Basics

What is a bruise?

Bruising is most commonly caused by a blunt and/or squeezing force trauma (Marshall, 1977; Nash and Sheridan, 2009; Venes, 2009). A bruise is the site of an injury/contusion and is technically defined as an 'extravasation of blood beneath an intact epidermis due to injury' (Capper, 2001). Three core criteria must be met for a bruise to occur: (i) the skin and tissues must be stretched and/or crushed with enough force to cause the small blood vessels to rupture but not break the surface of the skin (i.e. the trauma must be caused by a blunt force so that the skin is not punctured as to cause a laceration); (ii) there must be sufficient blood pressure within the blood vessels to move the blood from the damaged vessels to the surrounding areas; and (iii) the blood that leaves the blood vessels must be close to the surface of the skin to be visible with the naked eye for surface bruises (Langlois, 2007; Pilling *et al.*, 2010). Considering the three criteria listed above, what does this mean in the context of bruises that are seen post-mortem at a slaughter plant in cattle? If a carcass bruise is identified, the event that caused that bruise must have been forceful enough to rupture blood vessels. Thinking about animals moving through a handling facility, not all bumps and jostles will result in a bruise, but ones with some force behind them will – this force could come from the behaviour of the animal itself, the behaviour of other animals in the contemporary group, and/or animal handlers. Additionally, deep tissue bruises will not be readily visible on the surface, due to the

location of the trapped blood in the body tissues; this type of bruising may or may not be identified on the slaughter processing floor. The severity of a bruise is dependent on the amount and size of the blood vessels that are ruptured at the time of trauma (Marshall, 1977).

What do we know about how bruises are formed?

From personal experience, we have all seen bruises of many shapes and changing colours. The colour of a bruise reflects the physiological processes that have caused bruise formation and disappearance or 'healing'. As indicated, a bruise is formed from ruptured blood vessels underneath the skin. Blood contains haemoglobin, which is responsible for transporting oxygen from the lungs to the other tissues of the body (Langlois, 2007). The red discoloration in a contusion or bruise is the result of the haemoglobin that is present in the red blood cells that has been released from the damaged tissues due to the injury (Nash and Sheridan, 2009). The release of haemoglobin and/or red blood cells initiates an inflammatory response within the body which includes vasodilation and this attracts macrophages to the traumatized area (Nash and Sheridan, 2009). The redness of the skin and freshly escaped blood then changes to a blue or purple colour due to the deoxygenated venous blood moving into the various body tissues (Pimstone *et al.*, 1971; Nash and Sheridan, 2009). Macrophages then ingest the free red blood cells and degrade the attached haemoglobin on the red blood cells (Nash and Sheridan, 2009). Haemoglobin begins to break down by first converting to biliverdin, which contributes to the green colour seen in a healing contusion (Hughes *et al.*, 2004a). Biliverdin then is converted to bilirubin, which accounts for the yellow colour seen in a healing bruise injury (Vanezis, 2001). Throughout this process some of the escaped iron can combine with ferritin, which creates haemosiderin, which can have a brown appearance in tissues (Hughes *et al.*, 2004a,b). This process is illustrated in Fig. 5.1.

Bruise colour: what the black and blue is telling you

The colour of a bruise and how it relates to bruise age is the topic of great debate (Hamdy *et al.*, 1957a; McCausland and Dougherty, 1978; Langlois

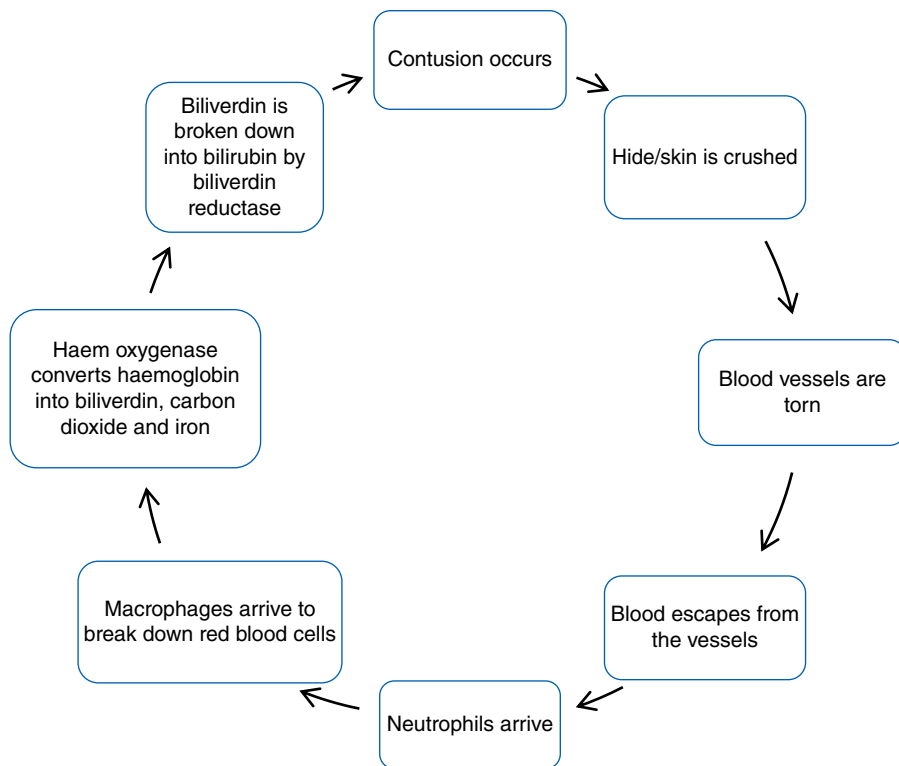


Fig. 5.1. Bruise pathophysiology cycle. (Information adapted from Vanezis, 2001; Hughes *et al.*, 2004a,b; Langlois, 2007; Nash and Sheridan, 2009.)

and Gresham, 1991; Langlois, 2007). When considering colour, the main objective or hope of understanding is to make some estimation of when the bruise occurred. As mentioned previously, in criminal investigations this is critical to understand. In the assessment of bruising post-mortem in livestock, professionals and researchers in the industry have been looking to bruise colour to provide some clues about when the bruise may have occurred. Bruise assessment is a mechanism to try to understand where bruises may be occurring and hopefully provide some ideas on how to mitigate risk factors associated with increased bruising. Unfortunately, the science of bruise colour is not exact, but it still is a useful tool to illuminate potential areas of opportunity. Despite some of the nuances of bruise colour, discussed below, bruise colour assessment post-mortem combined with visual observation of handling and management ante-mortem can provide valuable information to livestock producers and processors regarding critical control points within the pre-slaughter marking process.

There are many factors that affect the colour appearance of a bruise. Different species of animals can have varying bruise colour progressions and presentations (Hamdy *et al.*, 1957a; McCausland and Dougherty, 1978; Langlois and Gresham, 1991; Langlois, 2007). An older animal with less fat cover will bruise more easily than a younger animal with more fat cover. Statements that ‘a blue bruise is recent’ or ‘a fresh bruise will be red’ cannot be substantiated, because different tissues have various colour-retaining properties and there is inherent individual variation (Langlois, 2007). The perception of the colour of a bruise will change with the position of the trapped blood under the skin surface and the process of haemoglobin degradation (Langlois, 2007). Some authors have published guidelines for bruise colour appearance (Hamdy *et al.*, 1957a; Langlois and Gresham, 1991) but other experts claim that it is not possible to age a bruise solely based on colour (Langlois and Gresham, 1991).

Colour differences between fresh and old bruises

A general consensus seems to exist on the progression of the colour changes of a bruise but the exact time periods that match these colour changes are debated (Langlois and Gresham, 1991). Hamdy *et al.* (1957a) conducted a study in cattle that found that the red bruise colour could persist from 15 min to 2 days from the red blood cells and free haemoglobin in bovine tissue, green could be seen on days 3–4, and yellow and orange could be present on days 4–6 from the bilirubin in the tissues. The bruise colour cycle (Fig. 5.2) in livestock follows a predictable colour pattern, but the length of time of each colour stage can vary between livestock species. Studies were performed in cattle and rabbits and it was discovered that the order of the colour changes remained consistent between species, but that the age of the animals affected the rate at which the colour changes occurred (Hamdy *et al.*, 1957b, 1961b). McCausland and Dougherty (1978) conducted a study in calves that found the colour yellow appearing in the bruises within 48 h. There is much disagreement in the scientific community about only using colour to age a bruise (Langlois and Gresham, 1991), but a common theme shared in the literature is that yellow is a sign of 'older' bruising, 'old' being days. In practical application, the presence of yellow in a bruise at a slaughter facility likely indicates that the bruise did

not occur during the marketing process (assuming this process occurred over no more than 2–3 days).

Impacting Factors

Factors that can affect the appearance of a bruise can include the environmental temperature, the laxity of the tissues, whether the tissue is near a bone surface, the age of the individual when the bruise occurs, pre-existing diseases, force and velocity level at impact, and pre-existing bruise trauma to the location (Hamdy *et al.*, 1961a,b; Langlois and Gresham, 1991; Randeberg *et al.*, 2007). The location of the injury can affect the amount of haemoglobin released from the vessels due to a bruise; for example, if the area is low in connective tissue and high in adipose tissue and vascularity, there can be a larger amount of blood released, changing what the bruise may look like (Johnson, 1990; Vanezis, 2001). The environmental temperature had an effect on the bruise healing rate of chicken broilers, because birds kept in colder temperatures healed at a slower rate and the bruises had overall more yellow colour present in the tissues (Hamdy *et al.*, 1961a).

Several studies conducted in humans and rabbits have indicated that age of the individual can also have an effect on the bruising process both in appearance and in healing time, which increases with age (Howes and Harvey, 1932; Hamdy *et al.*,

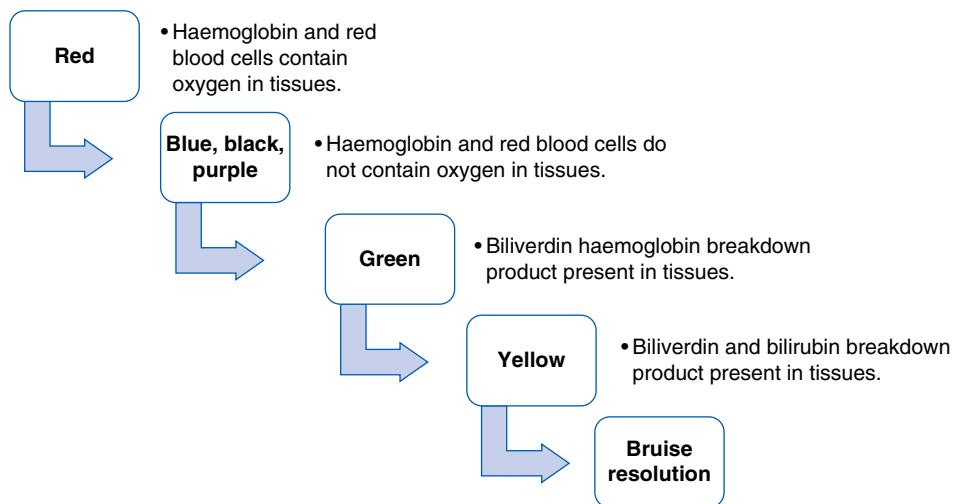


Fig. 5.2. Bruise colours and associated metabolite breakdown at various stages of bruise ageing. (Information adapted from Hamdy *et al.*, 1957a; McCausland and Dougherty, 1978; Langlois and Gresham, 1991; Langlois, 2007.)

1957b; Vanezis, 2001). Often elderly humans have thinning skin and the tissue around the blood vessels is weakened, thus impacting bruise occurrence and healing. The impact of age and body condition is a relevant point when thinking about cattle in particular, considering the range of ages seen between finished cattle and cull cows. Facilities that take a large range of cattle types and ages will potentially see a larger variation in the number of animals bruised.

The mass and the velocity of the object causing the bruise can affect the extent and severity of the bruise, but the sequence of visible and chemical changes of the bruise healing process remains constant (Hamdy *et al.*, 1957b). A study with pigs was conducted to evaluate histological and gross changes in the bruised tissues at 2, 4, 6 and 8 h where the bruises had been caused by low, moderate or high force levels. All pigs were anaesthetized during this study and the appearance of the bruises was similar for all force levels until the 0.5 h mark. At this time point the visibility of the bruise depended on the amount of force used to inflict the bruise (Barington and Jensen, 2016).

How Do We Prevent Bruising?

Bruises can provide many clues regarding how an animal was managed, but it is up to the animal care professionals and scientists to use the clues provided from bruising and investigate how and when they may have occurred. Bruises occur when a traumatic event has occurred and injured bodily tissues. This can reveal facility design improvement opportunities, potential animal handling concerns or even animal-to-animal variation in bruising susceptibility.

What are the risk factors?

There has been a considerable amount of research exploring risk factors associated with increased chance of bruising in cattle during the pre-slaughter transport and management process. A review of this literature will not be included here but some factors will be mentioned in brief. In short, practices or events that increase an animal's chance of experiencing a 'traumatic event' (e.g. a bump, jam, fall) often are the factors that have been shown to be connected to increased bruising in cattle. Sometimes these factors are related to the environment and sometimes these factors are related to

individual animal characteristics. Rough handling (Huertas *et al.*, 2010), mixing with horned animals (Shaw *et al.*, 1976; Strappini *et al.*, 2010; Mendonça *et al.*, 2016), transport through auction markets (Grandin, 2000; Strappini *et al.*, 2012) and inadequate facilities (Bethancourt-Garcia *et al.*, 2019) are some pre-slaughter factors associated with increased risk of bruising.

Why, when and how did that bruise occur?

Understanding where bruises come from, and most importantly finding ways in which to prevent them, requires you to think like a detective: be observant, be creative, and be proactive examining key control points within your systems to make improvements. Determining the cause of a bruise is like a criminal investigation; you start at the 'scene of the crime', i.e. the bruised carcass, and have to work your way backwards through the system to determine what may have occurred during the process to cause the bruise. This is not always a straightforward process and it does not always deliver a definitive answer, but, if nothing else, it provides clues to follow as you continue to focus on reducing the prevalence of bruising within your systems.

Bruises can occur after stunning but not after bleeding

A study was conducted in cattle with applying force to bruise the cattle before and after exsanguination and it was determined that a bruise could form before and after stunning, but not after exsanguination when the blood pressure of the animal is close to zero (Hamdy *et al.*, 1957b). Meischke and Horder (1976) stated that bruising is possible after an animal falls out of the 'knock box' after stunning but if the 'stun-to-stick' interval is decreased then this can decrease the amount of bruising. The depth of the injury can also affect the time it takes for the bruise to appear on the surface of the dermis; superficial bruises can appear almost immediately after the trauma occurs, while deep tissue bruising can take hours to appear or not appear at all on the surface, due to the body initiating the inflammatory response (Langlois and Gresham, 1991). Although there is potential for bruising to occur after an animal is rendered insensible at a slaughter facility, the extent of bruising at this time is likely low, due to the rate that exsanguination occurs and the handling process of the carcass

during this period. However, artefacts arising from post-mortem changes and equipment damage can resemble a bruise (Vanezis, 2001).

Being a detective to find causes of bruises

What clues can we take from a bruise? By visually inspecting a carcass, you can gather many clues about what may have caused a bruise and when it may have occurred. Bruises provide clues with their shape, location, colour, size, severity, number of bruises, and similarity between individual animals (i.e. more than one animal from a group has the same bruise). There are many things a bruise can tell you if you take the time to look. Consider the bruised carcasses in Figs 5.3, 5.4 and 5.5. The actual causes of these bruises are unknown to the authors. Common causes of the bruises shown in the figures are listed in the captions.

Examine the bruising in Fig. 5.3. This is a bovine carcass with significant bruising down the dorsal midline, with a concentrated area at about the mid-point of the carcass that is somewhat circular in shape. There is significant bruising in the concentrated area, with an entire area of bruising along the spine, loin and ribs emanating from that mid-way point. This is a relatively large area of bruising. The colour, particularly of the focal point, is dark red and there is no evidence of yellowing, suggesting this bruise is not 'old' and likely occurred at some point during the marketing process (that time could vary, depending on where this animal came from). The pattern suggests that something made forceful contact with the animal's back although it is impossible to know exactly what occurred. Thinking about handling events that cattle experience, one could speculate that this bruise may have been caused by an overhead gate banging into the animal's back or potentially the animal bumped into part of a trailer or load-out during loading or unloading. During research projects, observations are made of handling events (Lee *et al.*, 2017), and/or video footage is taken (Kline, 2018) to help inform what could have occurred so that it can be prevented from occurring in the future.

Figure 5.4 shows an image of a smaller bruised area at the tailhead of a cow. This bruise is bright red with no yellow present, suggesting it is not an 'old' bruise. The shape is circular and it is located right above a bony protrusion, which potentially increased the likelihood of a bruise forming in this instance. Once again, similar to Fig. 5.3, this animal



Fig. 5.3. Bovine dorsal bruising along the back and shoulders of the carcass observed on the processing floor. When back bruises are observed, a possible cause is low compartment height in trucks. Strappini *et al.* (2013) found that many bruises were caused by the stunning box door hitting the back. (Photo courtesy of Helen Kline.)

likely bumped into some overhead edge of a facility or trailer that the animal moved through or past.

Lastly, in Fig. 5.5 the bruised area is similar in shape to Fig. 5.4. This bruise is a little bit of a deeper red/purple colour. It is on the hip region of the carcass, so once again matching the location with knowledge of the handling process before slaughter: one can imagine that this animal bumped into a gate or corner catching a bony part of its body on a protruding edge with some force, causing this bruise to form.



Fig. 5.4. Bovine tailhead (near the base of the tail) bruising on the carcass observed on the processing floor. (Photo courtesy of Helen Kline.)



Fig. 5.5. Bovine hip bruising on the carcass observed on the processing floor. Possible causes of hip (loin) bruises are: (i) two cattle jammed in a truck door; (ii) horns; (iii) animal caught between the end of gate and a fence; or (iv) hitting sharp edges in the handling facility. (Photo courtesy of Helen Kline.)

Are bruises occurring inside or outside the slaughter plant?

These figures represent isolated examples of carcasses; we do not have information about bruising of other animals within the group or bruising of cattle in other groups. If any of these bruises (shape, location, colour) were repeatedly seen on carcasses from various groups of cattle, one can start to speculate that this may be occurring at the plant, i.e. if groups of cattle arriving from different origins have the same bruise markings, the plant is the location they have in common and were similarly exposed to. It is necessary to sample among multiple groups of cattle to gain

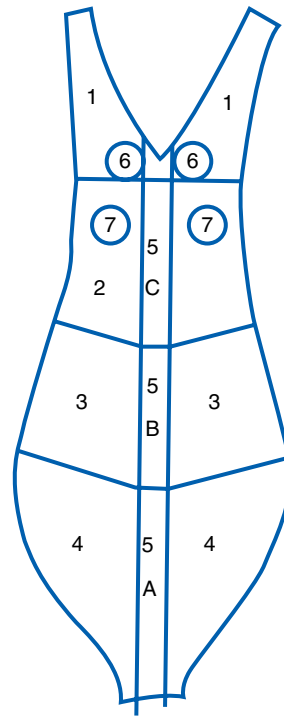


Fig. 5.6. Carcass diagram used for bruise scoring post-mortem and/or traumatic event scoring ante-mortem (adapted from Strappini *et al.*, 2012). Each region is identified by a unique number associated with that region.

a clearer understanding of when and where bruises may be occurring.

Bruise Monitoring and Scoring

Packing companies can monitor bruising within their facilities. Employees can visually assess bruising and provide feedback to facility management. There are numerous ways to track bruising effectively, and any method can be adapted to a particular plant system. Some current methods used in research studies utilize some variation of a carcass chart (example in Fig. 5.6) on which bruise location and colour are marked by an observer. Figure 5.6 is a carcass scoring diagram adapted from Strappini *et al.* (2012); the dorsal section has been further divided into three subsections (SA–C) as opposed to one section in the original diagram. This diagram can be used to identify where on the carcass a bruise was observed. A similar diagram can be used when observing live animal handling,

Instead of scoring bruising, the observer will score where an animal ‘bumped’ into equipment or facilities, indicating the location of a potential bruise. Anecdotally, the authors used this diagram when scoring traumatic events in live cattle and inverted it to help mimic more realistically the orientation of cattle moving through the facility. This information can be paired with bruise scoring post-mortem to provide some integrated information about the animal’s observed experience and the bruising pattern. Others studies have used similar diagrams (i.e. both sides of a carcass divided into regions) to track locations of bruises (Rezac, 2013; Lee *et al.*, 2017). These diagrams are useful for scoring location of bruising.

During the NBQAs, data is collected on the number, location and severity of bruises. The NBQA Bruise Key assesses severity of bruises visually by estimating the entire weight of the bruise on the carcass; the scale has 10 categories of severity, ranging in size from a quarter to an entire primal, but the severity is usually reported in larger categories of bruising: minimal = less than 0.45 kg trim loss; major = 0.46–4.54 kg trim loss; critical = 4.55–18.14 kg trim loss; extreme = loss of an entire primal (Eastwood *et al.*, 2017; Harris *et al.*, 2017). The authors recommend repeatability and reliability training for observers to ensure consistency in data collection.

Usually additional information, such as the origin of cattle (e.g. feedlot, farm, producer, sale barn), distance travelled, presence of horns and type of cattle (e.g. cow, bull, steer, heifer), should be collected as well in order to provide some information regarding the pre-slaughter management of the animals. As discussed above, some of the individual animal characteristics and management practices can increase the risk of bruising and therefore documenting these parameters may be helpful for in-plant bruising investigations. Performing targeted audits of different groups of animals at the processing facility is a way to measure and manage bruising. Incorporating a periodic bruise monitoring system into a quality assurance plan is a valuable way to benchmark bruising, target system changes and track improvement.

Evaluating pre-slaughter handling to find potential causes of bruising

In addition to scoring bruising on carcasses, it is often helpful to pair carcass bruising with an assessment

of the handling prior to stunning, for example during loading, transport, unloading or movement within the slaughter facility. Bruising is sometimes challenging to monitor because obviously bruise prevalence cannot be assessed ante-mortem; thus, by the nature of bruising itself, it remains out of sight and out of mind until the opportunity for prevention has passed. Instead, the evaluation of handling, transport and movement ante-mortem to identify events that could potentially cause bruising needs to happen in tandem with the visual assessment post-mortem. These types of observations include watching animals unload at the facility and recording any bumps, jams or ‘traumatic’ impacts with the trailer, facility, handling aids or other animals. Additional observations could potentially occur at loading and during transport to the slaughter facility, depending on the resources and time available to do so. It is helpful to record where these ‘traumatic’ events occurred on a diagram to be used later in comparison with carcass bruising from those specific groups of animals. Although observing large groups of animals and assessing animals on a group (‘lot’) basis is helpful and provides valuable information, it is also helpful to focus on individual animals. By making observations on a specific animal and maintaining its identity as it moves through the slaughtering process, one is able more assuredly to make some inferences about the bruises found.

Weighing bruised trim meat

Additionally, it is possible to assess carcass loss (yield loss from bruised meat that has been trimmed and removed from the carcass) or damage by evaluating carcasses after trimming is complete. Collecting and weighing the bruise trim and the location in which this trim was located can provide valuable information on bruising. There are numerous ways to monitor bruising and they can be adapted to individual plants to help answer welfare and production questions.

Conclusion

Identifying the critical control points for bruising in the livestock supply chain is an ongoing process. By examining each step in the process, both the scientific community and abattoir management can evaluate the risk factors for bruising and develop methods to equip the livestock industry with relevant information that facility personnel can readily

apply to current animal handling programmes. To decrease bruising requires an industry-wide effort to animal handling and well-being of cattle. Identifying the original cause of a bruise found on a carcass post-mortem is a complex and challenging task. The science of bruise assessment is not so precise that we can identify the hour, minute, location and day that a bruise occurred. What we can do is pair post-mortem bruise evaluation with ante-mortem handling and management evaluation to make some informed estimates of what could be targeted within the pre-slaughter system to improve our processes.

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6

Behavioural Principles of Stockmanship and Abattoir Facility Design

TEMPLE GRANDIN*

Department of Animal Science, Colorado State University, USA

Summary

Cattle, pigs, sheep and other livestock are very sensitive to visual stimuli and intermittent sounds. Removal of distractions from handling facilities will improve animal movement. Handlers also need to understand basic behavioural principles such as the flight zone and the point of balance. Low-stress handling of cattle and pigs requires moving small bunches. Good handling will require more walking to move small groups. Non-slip flooring is essential in stun boxes, races, unloading ramps and alleys. There are some species differences. Funnel-shaped crowd pens work well for cattle and sheep but poorly for pigs. To prevent pigs from jamming, there should be an abrupt entrance to a single file race. This chapter also contains a list for solving problems with handling and restraint equipment.

Learning Objectives

- Learn to find and remove visual and auditory distractions that cause animals to balk, turn back, or refuse to move.
- Understand flight zone principles and point of balance when moving livestock.
- Learn how to design lairages, races, stun boxes and restrainers.
- Solve and fix handling problems that are detrimental to animal welfare.

Introduction

Good stockmanship when handling animals will improve both efficiency and animal welfare. When

animals become difficult to move or handle, it is often due to the animal being fearful. Scientific research clearly shows that animals can experience fear (Davis, 1992; Panksepp, 2011). Stress hormone cortisol levels are similar during restraint, for veterinary procedures on the farm, and at the abattoir (Grandin, 1997a; Mitchell *et al.*, 1988). Novel experiences are often frightening to animals. In both cattle and sheep, the novelty of the abattoir environment may be a major cause of agitated fearful behaviour. Deiss *et al.* (2008) and Bourguet *et al.* (2010) showed that sheep and cattle that were more reactive to sudden novelty on the farm were also more reactive at slaughter. Therefore, the animals are more likely to be reacting to being in a novel place instead of being afraid of getting slaughtered (see Chapter 1). Calm animals are much easier to handle than frightened excited animals. People working with livestock need to understand that if an animal becomes highly agitated and fearful, 20–30 min is required for the heart rate to return to normal (Stermer *et al.*, 1981) and for stress hormones to decline (Lay *et al.*, 1992a,b). The best approach is to handle animals quietly so that they remain calm.

Signs of Agitated Fearful Livestock

People handling livestock need to be able to recognize when animals are becoming frightened. When an animal is becoming increasingly

* Email: cheryl.miller@colostate.edu

stressed, the following behavioural signs may be visible:

- the animal suddenly raises its heads in response to a stimulus;
- defecation with loose faeces;
- tail switching in cattle and horses (Grandin, 2017); and
- whites of the eyes show (Janczak *et al.*, 2008; Core *et al.*, 2009).

People moving and handling livestock need to understand how the animals perceive their surroundings. Cattle, sheep, pigs and other animals are extremely sensitive to things that move rapidly, shadows and reflections on shiny metal (Grandin, 1980a,b, 1996; Tanida *et al.*, 1996; Lanier *et al.*, 2000). These visual distractions can cause animals to balk and refuse to move through a race or alley (Grandin, 1996). Removal of the distractions will usually improve animal movement. Later in this chapter, there will be further information on finding and removing distractions.

Vision and Hearing

Vision in cattle, pigs and sheep

Cattle, sheep and pigs have wide-angle vision and they can almost see all around themselves without turning their heads (Prince, 1970; Kilgour and Dalton, 1984; Hutson, 2014). Grazing animals, such as horses and sheep, have a horizontal band of sensitive retina (Shinozaki *et al.*, 2010). This enables them to easily scan their surroundings for danger during grazing. Grazing animals do have depth perception (Lemmon and Patterson, 1964), but it is likely that their depth perception is poor. Animals may stop and put their heads down when they see either a shadow on the floor, or a change in the surface such as moving from a concrete to a steel floor. They need to determine if the floor is safe to walk on. Farm animals are partially colour blind and they do not see red. Red may appear as grey or black. The retina of cattle, sheep and goats is most sensitive to yellowish-green (552–555 nm) and bluish-purple light (444–455 nm) (Jacobs *et al.*, 1998). This may explain why yellow safety vests may be a major distraction. The dichromatic vision of the horse is most sensitive at 428 nm and 539 nm (Carroll *et al.*, 2001). Dichromatic (two-colour) vision where the retina receptor for red is absent may also explain why livestock are so sensitive to sharp contrasts of light and dark.

Animal movement is highly influenced by vision

Compared with facilities on a farm, an abattoir usually has much more activity around the handling facilities. Solid sides are recommended on stun boxes and single file races to block the animal's view of nearby people, vehicles, conveyors and other equipment outside the race (Grandin, 1980a,b). Heather Ercolano (2018), an animal welfare specialist at a large slaughterhouse for cull dairy cows, experimented with both open and solid sides on the single file race (chute) that led to the stunner. The cows moved more easily when the solid sides were added. Muller *et al.* (2008) found that cattle remained quieter during restraint when they were not able to see a person standing beside them. In existing slaughter plants, experimentation should be done to determine if adding a solid side improves movement. Large pieces of cardboard work well for this purpose.

Cattle, pigs and sheep do not like to enter dark places. Adding a light to illuminate a dark stun box entrance can improve animal movement (Van Putten and Elshof, 1978; Grandin, 1982, 2001). A third principle on how vision has an effect on animal movement is that livestock may balk and refuse to enter a stun box or race that appears to be a dead-end. Cattle will often enter a stun box more easily if they can see light through either the headholder or a small window is installed in the front of the box. To prevent the incoming animals from seeing people or moving equipment, a solid shield should be located approximately 1 m in front of the box. In summary, there are three basic principles on how vision affects animal movement.

- Animals balk and refuse to move forward when they see visual distractions ahead of them (Grandin, 1980a,b; Tanida *et al.*, 1996) (see [Box 6.1](#)).
- They are more willing to move from a darker area towards a more brightly illuminated area (Van Putten and Elshof, 1978; Grandin, 1982, 1996, 2001).
- They refuse to move towards a place that looks like a dead-end. This can be caused by layout mistakes in stun boxes, drive alleys and at the junction between a single file race (chute) and a crowd pen. An animal standing at the entrance of a single file race should be able to see two or three body lengths up the race. If the single file race is bent very abruptly at the junction, the animals may refuse to enter it.

Box 6.1. Checklist of all types of distractions that cause livestock to balk and refuse to move forward into a race, stun box or restrainer

To locate distractions, walk through the races and look for things that move, create contrasts or make sudden intermittent noise. Animals will often stop and look at distractions and refuse to move forward. Below is a checklist of common distractions that may cause animals to balk, turn back or back up.

- Seeing people or moving equipment through the headholder of the stun box. To remedy, install a solid shield 1 m (3 ft) in front of the headholder. This will block the view of activity in front of the box.
- Seeing motion through holes or openings around the stun box door. Common sources of motion are the person shackling the animals, moving conveyors or hoists.
- Air blowing toward the approaching animals. Adjust the ventilation system. There may be time-of-day effects. Animals may start refusing to move into the stun box when additional ventilation fans are turned on.
- Loud sudden air hissing or metal clanging (Talling *et al.*, 1998).
- Tailgate on the stun box does not open sufficiently high. Entering animals either bump their shoulders, or almost bump them, on the low gate. The remedy is to raise the gate higher.
- Coats on fences, paper cups on the floor or hoses on the floor. They should be removed.
- Reflections on shiny metal (Fig. 6.2). Move ceiling lamps or turn off lamps to eliminate the reflections. Experiment with turning different lights on and off.
- Animals refuse to enter a dark area. Use directional lighting to illuminate a dark stun box or race entrance. Animals will move towards the light (Van Putten and Elshof, 1978; Grandin, 1982). The light should never be directed into the eyes of approaching animals.
- Animals stop at drains or a change in flooring such as moving from a concrete to a metal floor. Locate drains outside the alley where animals have to walk. If the drain cannot be moved, handlers should be trained to allow the lead animal time to stop and look at it. After the lead animal walks over the drain, the others will follow it.

Hearing in farm animals

Farm animals have sensitive hearing and are sensitive to high-pitched sounds. They can hear high-frequency sounds that people cannot hear. The human ear is most sensitive to sounds in the 1000–3000 Hz range. Cattle and horses are most sensitive to frequencies at 800 Hz and above (Heffner and Heffner, 1983). Sheep can hear up to 10,000 Hz (Wollack, 1963). High-pitched, intermittent sounds are also more likely to cause cattle or pigs to react (Talling *et al.*, 1998; Lanier *et al.*, 2000).

Designing equipment to reduce noise will help keep animals calmer. Air hissing should be muffled and metal clanging and banging should be silenced. Some equipment companies are building moving parts of equipment from heavy plastic panels to reduce noise (Fig. 6.1). Another advantage of plastic panels is that they are less reflective. A smartphone app can be used to monitor noise (Iulietto *et al.*, 2018) and assess the effectiveness of noise reduction methods.

Handlers should watch where animals point their ears. Cattle, sheep and many other animals will point their ears towards things that attract



Fig. 6.1. The sliding panels that restrain the top of the bovine's neck and the box exit door are both constructed from thick plastic panels. This helps to reduce noise. (Photo courtesy of Temple Grandin.)

their attention. Yelling and screaming at livestock is highly stressful (Waynert *et al.*, 1999; Pajor *et al.*, 2003). Unlike equipment noise, yelling has intent; the animals know that the handler is yelling at them.



Fig. 6.2. Cow's-eye view into a stun box with a head yoke. Note the reflections on the shiny metal. Moving a ceiling light may eliminate these reflections. Make sure that an approaching animal does not see people through the head yoke. This stun box has a good non-slip floor. (Photo courtesy of Temple Grandin.)

Flight Zone and Point of Balance

Flight zone principles for moving livestock

Handlers need to understand the behavioural principles of the flight zone and point of balance for moving cattle, pigs, sheep and other animals. To keep animals calm and move them easily, the handler should work on the edge of the flight zone (Grandin, 1980a,b, 2014; Grandin and Deesing, 2008) (Fig. 6.3). If cattle rear up or become agitated in a single file race, the handler should back up and retreat out of the animal's flight zone. Most animals will stop rearing and calm down when the handler backs out of their flight zone. The flight zone is the animal's personal space, and the size of the flight zone can vary from 0 m from a person to over 10 m.

Hedigar (1968) defined the process of taming an animal as removal of the flight zone to the point that the animal allows people to touch it. When a person penetrates the flight zone, the animals will turn and move away. The size of the flight zone will vary depending on how wild or tame the animals are. Completely tame animals that have been trained to lead have no flight zone. Usually, they should be led instead of being driven. If an animal

is trained to lead with a halter (head collar), it may be advisable to lead it into the stun box. Extensively raised animals that seldom see people will have a larger flight zone than animals that see people every day. When cattle are handled quietly, their flight zone will become smaller.

Understanding the flight zone

The size of the flight zone is determined by conditions on the farm where the animal was raised. There are three factors: (i) the amount of contact with people; (ii) the quality of the contact with people – calm and quiet versus shouting and hitting; and (iii) animal genetics. Animal temperament (flighty versus calm) is a heritable behaviour trait (genetic trait) (Hearnshaw and Morris, 1984; Voisinet *et al.*, 1997a,b; Zambra *et al.*, 2015; Littlejohn *et al.*, 2016). Animals that see people every day on the farm when they are fed will usually have a smaller flight distance than animals on extensive pastures that see people only a few times a year. It is possible to have indoor intensively raised animals with large flight zones. This is caused by people never entering their pens during fattening. All species of livestock *must* become accustomed to people walking inside their pens before they come to an abattoir. Livestock that are properly acclimatized to people will quietly move away when a person walks through their pen. If pigs pile up and squeal during handling at the abattoir, this is usually an indicator that people never entered their pens on the farm.

Use the principle of pressure and release

To move extensively raised animals in a calm, controlled manner, the handler should work on the edge of the flight zone. The handler penetrates the flight zone to make the animals move and he backs up when he wants them to stop moving. The handler should avoid the blind spot behind the animal's rear. Animals may become agitated when a person is inside their personal space and the animals are unable to move away. This often occurs in either a race or small pen. If livestock turn and run back past the handler while being driven down a drive alley in the lairage, overly deep penetration of the flight zone is a likely cause. The handler should immediately back up and retreat from inside the flight zone when the animals give the slightest indication that they will turn back. Cattle and other

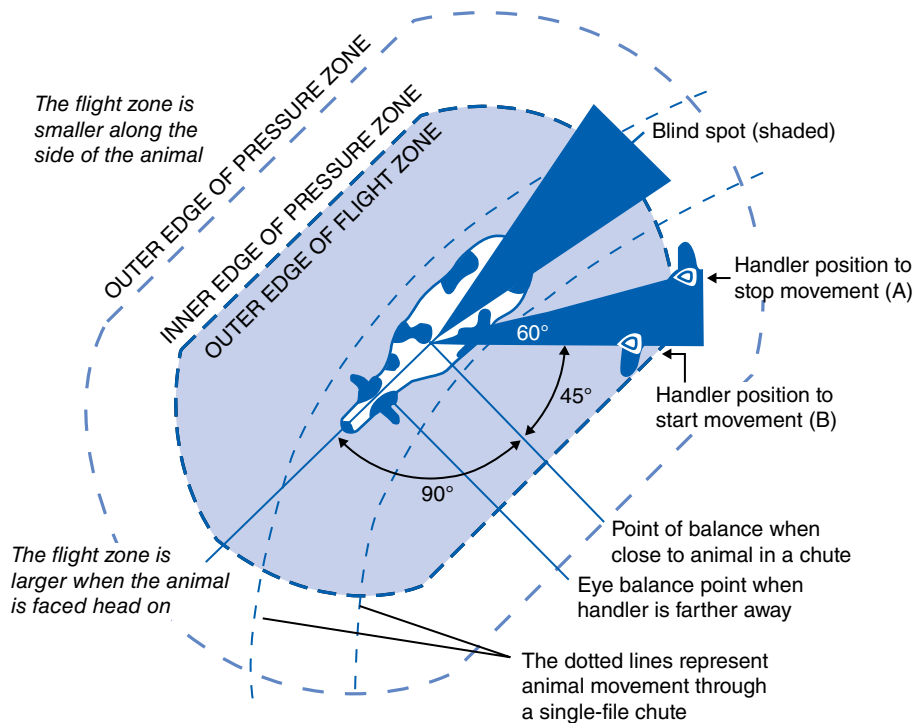


Fig. 6.3. Flight zone and point of balance. To move a single animal forward, the handler must be behind the point of balance and stay out of the blind spot directly behind the animal. When the handler is close to the animal, the point of balance is at the shoulder. When the handler is farther away, the point of balance may move forward to just behind the eye. When the handler is on the outer edge of the pressure zone, the animal becomes aware of the handler's presence and turns around and looks. When the outermost edge of the flight zone is penetrated, the animal moves away. (Diagram courtesy of Temple Grandin, www.grandin.com)

livestock with very large flight zones may immediately turn back and run out of a lairage pen they have just entered. They are attempting to get away from the handler and they can be dangerous. Plant managers and livestock buyers need to work with producers to reduce problems with wild livestock with large flight zones.

Point of balance principles

The flight zone diagram (Fig. 6.3) shows the correct positions for the handler to move livestock through a single file race. The handler should stand behind the point of balance at the shoulder to make an animal go forward and in front of the point of balance at the shoulder to make an animal back up (Kilgour and Dalton, 1984; Smith, 1998; Grandin, 2014). The most common mistake that people make is to stand in front of the point of balance and poke the animal on the hindquarters to make

it move forward. This gives the animal conflicting signals and confuses it. The handler must be behind the shoulder when he wants to urge the animal forward. Another effective method to move animals forward in a single file race is to walk quickly by them in the opposite direction of desired movement (Fig. 6.4). The animal will move forward when the point of balance is quickly crossed.

Pressure zone or zone of awareness

When a person enters the edge of the flight zone, the animals will turn away from the person and move forward. When the person is just outside the flight zone, a group of cattle, pigs or sheep may turn and face the handler. This is called the pressure zone (Fig. 6.3). Other names for this zone are zone of awareness, or zone of influence. When a person is in this zone, they are outside the flight zone but the animals are watching and they know a person

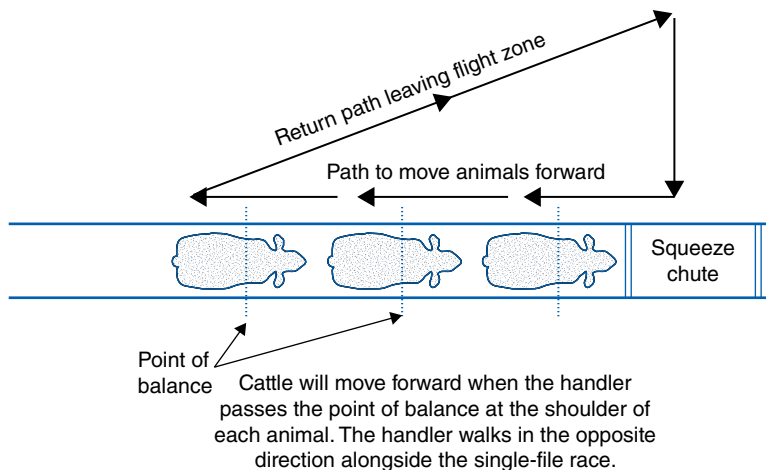


Fig. 6.4. Handler movement pattern to induce cattle, pigs or sheep to move forward in a chute or race. (From Grandin, 1998, in Gregory, N.G. (ed.) *Animal Welfare and Meat Science*. CAB International, Wallingford, UK, p. 47.)

is there. On a pasture, cattle that are really far away will ignore you and continue to graze.

Use the bubble for moving groups out of pens

When cattle, sheep or pigs move past a handler standing at the gate, they will flow around the handler and keep the handler on the edge of their flight zone. It is like a 'force field' around the stock person. If the handler is positioned at the correct location at a gate, the animals will flow around the bubble formed around the person (Fig. 6.5). After movement is started, the handler should continue standing slightly outside the edge of the flight zone but inside the pressure zone. This method is very effective for moving animals out of large lairage pens. The flight zone diagram (Fig. 6.5) is mostly used in the single file race, because it prevents the animal from turning around, or for moving single animals, such as dairy cows or sows. When a group of animals is flowing out of a pen, the handlers must not attempt to keep moving back into the pen to stay behind the point of balance.

Timing bunches of cattle, pigs or goats to prevent turning around

Cattle, pigs and other livestock have a natural instinct to want to go back to where they came from. If they are allowed to stop too long in a drive alley or crowd pen, they will turn around to return to the lairage pens. When handlers learn to time

bunches, the animals can be kept moving and will not have the opportunity to turn around.

Moving small bunches and using following behaviour

Good stockmanship and low-stress handling at an abattoir will require more walking to bring small bunches of animals up to the crowd pen (forcing pen) that leads to the single file race (chute) (Fig. 6.6). Management in each facility should determine the number of animals that work well. A basic principle is that cattle, pigs and goats should be moved in small separate bunches. Sheep have the most intense following behaviour and larger bunches can be used. They can often be moved into the single file race in a continuous flow.

The crowd pen that leads to the single file race should be filled *half* full so that cattle and pigs will have room to turn. All livestock will follow the leader and handlers can take advantage of this natural behaviour to move animals easily. Cattle and pigs will enter a single file race more easily if it is allowed to become partially empty before attempting to fill it. A partially empty race takes advantage of following behaviour, because it provides enough space for four to ten animals to enter while following the leader. This will enable the group to pass through the crowd pen without stopping. Doing this will help prevent problems caused by animals stopping and having the opportunity to turn around.



Fig. 6.5. When the handler positions themselves in the correct position at a gate, pigs, cattle and sheep will flow around the bubble that is formed along the edge of the flight zone. (Photo courtesy of Temple Grandin.)



Fig. 6.6. Round crowd pen that has been filled half full. Note that the crowd gate is not pushed up tight against the animals. This design takes advantage of the natural behaviour of cattle and sheep to go back to where they came from. (From Grandin, T., 1998, in Gregory, N.G. (ed.) *Animal Welfare and Meat Science*. CAB International, Wallingford, UK.)

Trained leader animals

Trained goats or sheep will lead sheep through stockyards or lairages (Hutson, 2014). Lead animals also work really well for moving sheep on and off trucks. A specialist lead sheep or goat should be used for different handling procedures. Training the lead animals will be easier if one leader is trained to unload trucks, another is trained to load trucks and a third animal is trained to lead sheep out of pens and through the stockyards. In confined spaces such as trucks and small lairage pens at the slaughter plant, lead animals are recommended instead of

dogs. Dogs can be highly stressful for sheep (Hemsworth *et al.*, 2018). Lead sheep have been working very successfully for many years at the largest sheep slaughter plant in the USA.

Livestock become fearful when alone

A single cow in a pen that becomes agitated in an attempt to join its herdmates has caused many accidents that have severely injured people. Never get in a small, confined pen with a single, agitated bovine. Isolation away from herdmates is highly stressful for all livestock (Bates *et al.*, 2014). There are inherited genetic differences in an animal's response to isolation (Zambra *et al.*, 2015). It may jump a fence or run into people. If a lone animal becomes agitated, put some other animals with it.

Driving aids for moving livestock

Stock people should be trained to be quiet and avoid yelling. They need to learn how to move animals calmly and not be constantly poking them with a driving aid. A common mistake is to make lots of noise by banging driving aids on fences and other equipment. If the animals refuse to move, there may be distractions that need to be removed.

An electric goad should never be used as a person's primary driving tool. The World Organisation for Animal Health (OIE, 2016a,b) code recommends that only battery-operated goads should be used. Electric prod use will increase cortisol (stress hormone) levels in cattle and pigs (Hemsworth *et al.*, 2011) and fast movements by stock people and grabbing animals were detrimental for sheep

(Hemsworth *et al.*, 2018). The OIE (2016a,b) code also states that electric goads should not be used on sheep, horses or very young animals such as piglets. The goad should only be picked up when other non-electrified methods fail to move an animal. Research has shown that the attitude of the handler towards the animal is better when shocks are not being used (Coleman *et al.*, 2003). Electric goads are also really detrimental to both meat quality and animal welfare (Benjamin *et al.*, 2001; Warner *et al.*, 2007; Ferguson and Warner, 2008; Edwards *et al.*, 2010a,b). Cattle that become behaviourally agitated have poor meat quality (Gruber *et al.*, 2010). However, a brief shock on the hindquarters is preferable to hard tail twisting or beating animals. Tail twisting is illegal in the UK. After the stubborn animal is moved with the electric goad, the goad should be put away. A plastic bag taped to the end of a stick or a flag is an excellent tool for moving cattle and directing their movement in crowd pens. For pigs, panels work really well in narrow alleys (McGlone *et al.*, 2004). Hard plastic panels are too heavy for people to carry all day. Plastic flags with a hand hold in the middle are effective for moving market-weight pigs out of lairage pens (Fig. 6.7). Some specialists in low-stress livestock handling prefer to use no driving aid. One reason for this recommendation is that it is difficult to stop people from constantly waving them. A skilled person can move the animals by making small movements of their bodies. Driving aids must never be applied to sensitive parts of the animal such as



Fig. 6.7. Flag with both a handle and a centre handhold for moving pigs. It is much lighter and easier to use than a panel. This photo also shows excellent non-slip flooring. (Photo courtesy of Temple Grandin.)

the eyes, ears, nose, rectum, genitals or udder. The OIE code (OIE, 2016a,b) states:

Painful procedures (including whipping, tail twisting, use of nose twitches, pressure on eyes, ears or external genitalia) or the use of goads or other aids which cause pain and suffering (including large sticks, sticks with sharp ends, lengths of metal piping, fencing wire or heavy leather belts) should be not be used.

Problems that originate at the farm

Problems that originate at the farm may make livestock difficult to handle at the slaughter plant. There are some cattle or pigs that may be difficult to move even when they are handled in well-designed facilities. This may be caused by lameness (difficulty walking) or being fed excessive amounts of beta agonist growth promoters (Peterson *et al.*, 2015). To solve these problems, conditions on the farm will need to be improved. Handlers should keep records to determine which producers send in animals that have handling problems. In one abattoir, problems with high numbers of downed non-ambulatory pigs were corrected by: (i) the producers reducing use of ractopamine beta agonists; (ii) genetic selection of breeding stock for good foot and leg conformation; and (iii) walking through the finishing (fattening) pens to get the pigs accustomed to people walking through them. Animals that are accustomed to being moved on the farm will be easier to handle (Abbot *et al.*, 1997; Geverink *et al.*, 1998; Lewis *et al.*, 2008; Krebs and McGlone, 2009). Brown *et al.* (2006) found that having people walk the finishing pens once or twice a week made pigs easier to drive at the slaughter plant. This teaches the pigs to move away quietly when people walk through them. High doses of beta agonists may have a detrimental effect on pig or cattle handling (Grandin, 2010; Peterson *et al.*, 2015; Ritter *et al.*, 2017).

Stockyards, Lairage and Races

Design of stockyard and lairages

A basic requirement is that cattle and sheep that are held overnight must have sufficient space to all lie down at the same time (see Chapter 11). The number of animals that can be carried in a truckload is usually used to determine the size of each lairage pen. Pens are usually designed to hold one or two truckloads.

Resting time in lairage

Pigs require resting time in the lairage to preserve pork quality. At all times, pigs must always have sufficient space for all the animals to lie down at the same time (see Chapter 11). One hour is the minimum rest time and 2–4 h is recommended (Milligan *et al.*, 1998; Warriss, 2003). Pigs transported a short distance do not have sufficient time to calm down after being loaded and they need a longer resting time (Garcia-Celdran *et al.*, 2012). Lambs may benefit from overnight lairage or a 6–12-h holding time (Liste *et al.*, 2011; Liu *et al.*, 2012) (see Chapter 4).

One-way flow through the yards

Lairages and stockyards should be laid out to have one-way flow through the pens. The animals enter at one end of a pen and exit through the other end. Herringbone designs with the pens on a 60–70-degree angle work well (Fig. 6.8 and see Chapter 11). Do not put the pens on a 45-degree angle, because animals are more likely to become stuck in sharp corners. Pens can also be laid out in a straight configuration. Long narrow pens may help reduce fighting. Gates should be made to open on an angle. On a 2.5 m wide alley, use 3 m gates; and on a 3 m wide alley, use 3.5 m gates. The animals enter the pens through the outer alleys and move to the stunner through the central alley.

Use of non-slip flooring

A rough broom finish on concrete will quickly wear smooth. For pigs and sheep, printing the pattern of expanded metal mesh into the wet concrete is recommended. The grooved floor shown in Fig. 6.6 will also work well. Cattle and other large animals will need deeper grooves. A 20 cm × 20 cm diamond pattern that has grooves 2.5 cm deep is effective. Concrete slats can be used in the pens but the drive alleys should have solid concrete. More information on flooring can be found in the open-access sources of Grandin (2008) and www.grandin.com.

Handling intact bulls

Bulls fight more than steers. Mixing strange bulls can increase meat quality problems due to fighting and mounting. Bulls that have been reared on the farm in

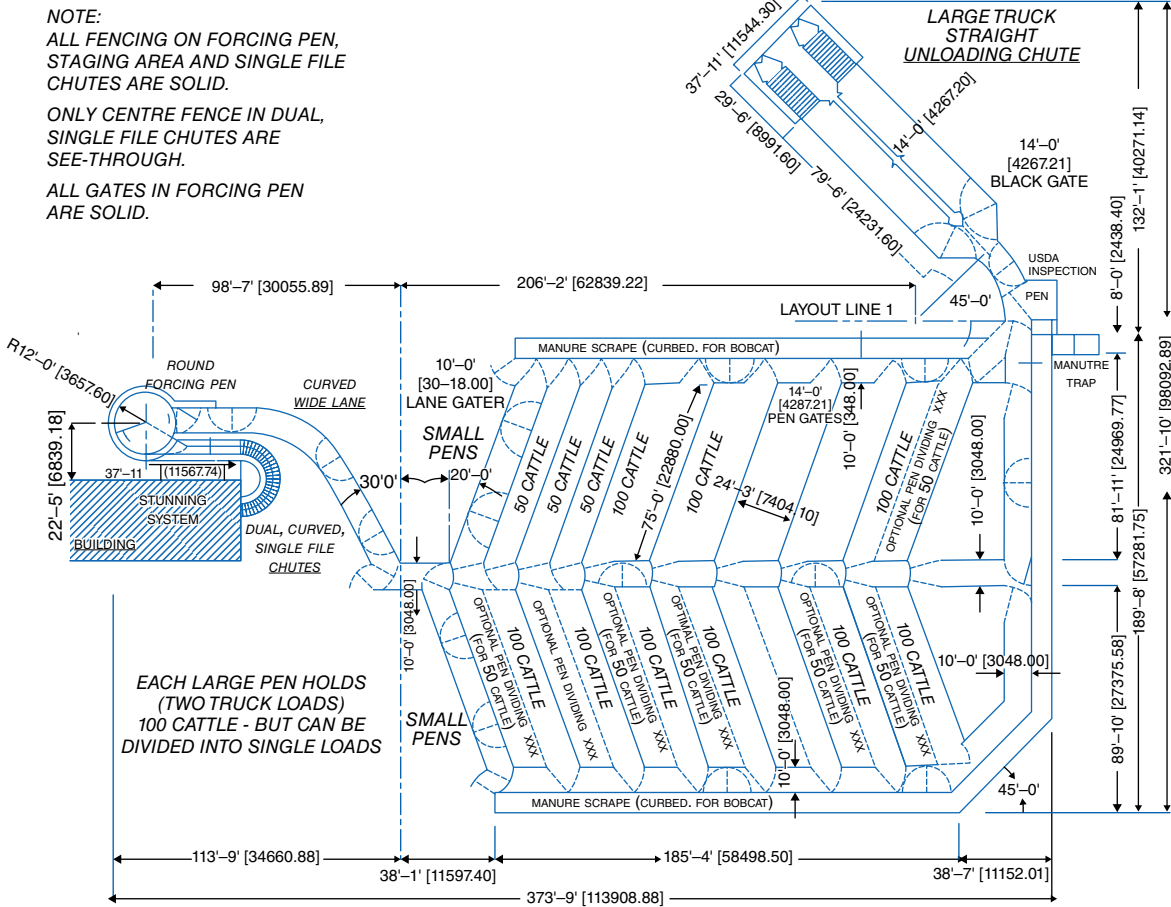
groups can be held in a regular group pen with their penmates. Do not mix bulls from other pens.

There are problems when bulls arrive as singles. If they are penned together, they will mount each other and fight. This is likely to cause poor-quality dark cutting meat or injuries. To prevent mounting and aggression, they can be unloaded into single file races. If this system is used, they should be delivered in a ‘just in time’ manner so that they spend less than an hour in single file races. This system should only be used when small numbers of one or two bulls are brought to an abattoir.

Design of single file race system

Single file races work well for cattle and sheep because they are animals that naturally walk in single file. Cattle will walk in single file when moving from pasture to pasture on the farm. Both of these species have a strong natural behaviour to follow the leader. In abattoirs, single file races are essential for low-stress handling of extensively raised cattle and sheep that have had little contact with people. In most countries, cattle and sheep are handled in systems with single file races and crowd pens to direct animals to the stun box. Since slaughter houses have many distractions, such as moving equipment and people, the use of solid sides on crowd pens, races and stun boxes is strongly recommended (Grandin, 1980a,b, 2014). This is especially important for animals with large flight zones. Blocking an animal’s vision may result in calmer animals (Mitchell *et al.*, 2004; Muller *et al.*, 2008).

In small abattoirs in developing countries, a tame single bovine or water buffalo can be led to the slaughter area. Stunning can be performed while the animal is standing. In larger abattoirs, it is recommended to use a race and crowd pen system. All races should have solid outer fences to prevent the animals from seeing people, vehicles, moving equipment or other distractions outside the fence. Animal entry into the race can sometimes be facilitated if solid shields are installed to prevent approaching animals from seeing people standing by the race. A curved single file race is especially recommended for the moving of cattle and other large animals (Grandin, 1980a,b) (Fig. 6.9). A curved race works well for two reasons. It prevents incoming animals from seeing activity up ahead and it takes advantage of the natural behaviour to go back to where they came from. Pigs will move



DIVERT AND PEN GATES IN WIDE LANES ARE LONGER THAN LANE WIDTH, SO THEY OPEN AT AN ANGLE AND ELIMINATE ANY POSSIBLE SHARP EDGES.

Fig. 6.8. Stockyard lairage laid out in a herringbone pattern. (Diagram courtesy of Temple Grandin.)

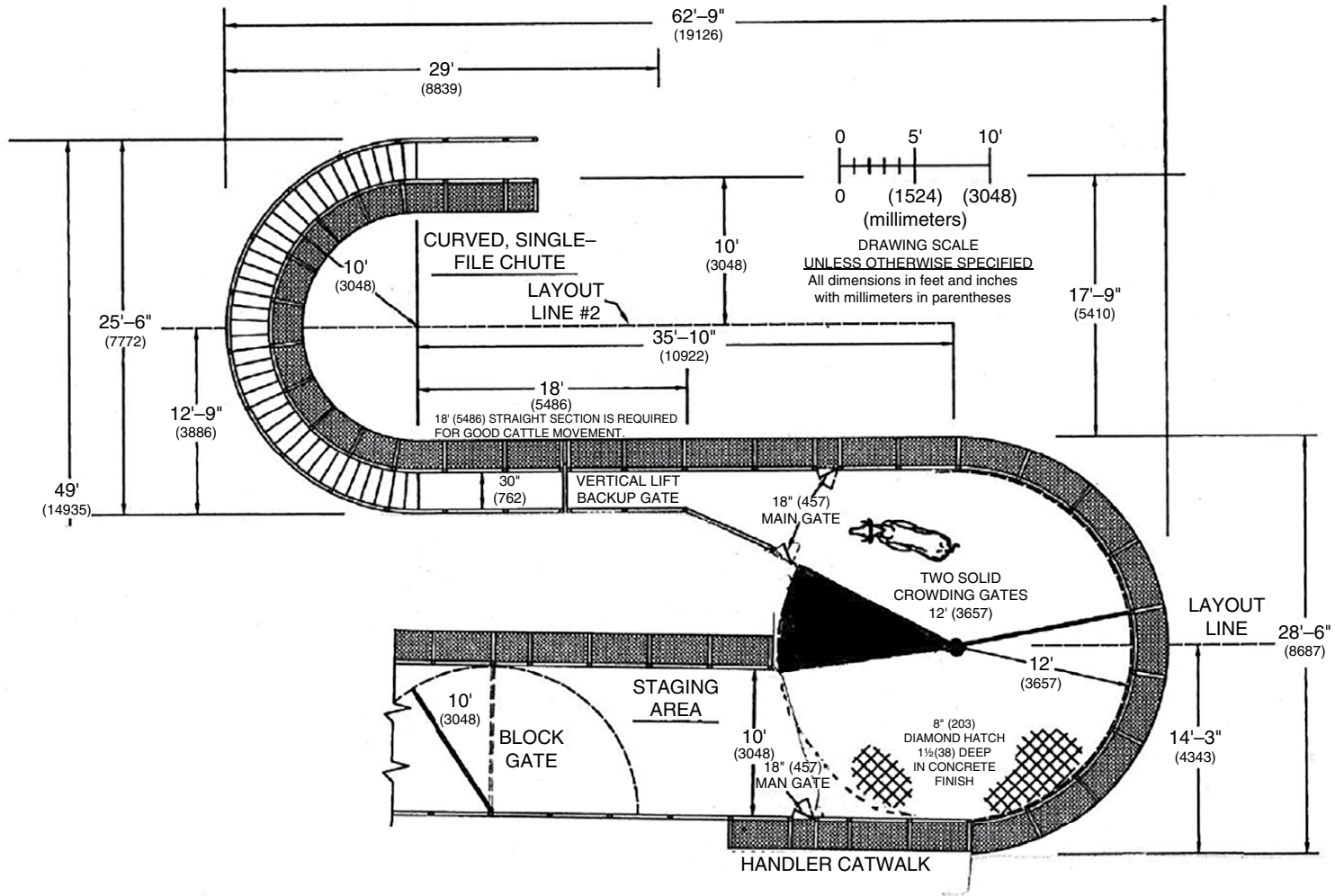


Fig. 6.9. Round crowd pen and curved race system for cattle. The round crowd pen has a 3.5 m (10 ft) radius. To facilitate cattle entry, there is a 5.4 m (18 ft) section of straight race before the curve. This enables the animal to see a place to go. One of the most common mistakes is bending the race too sharply where it joins the crowd pen. The stock person stands on the black shaded area to encourage the cattle to circle around him. This is called 'working the crowd gate pivot'. The crowd gate is latched as shown in Fig. 6.6. A small version of this design will also work with sheep. The round crowd pen radius can be shortened to 2.5 m (8 ft).

easily in a straight race (Grandin, 1982). **Figure 6.9** shows a round crowd pen and curved race that will work well for cattle and other large livestock. A stockperson stands in the black shaded area and uses a flag to encourage the animals to circle around. This takes advantage of the natural behaviour to go back to where they came from. The person stands at the pivot point of the crowd gate. This often works more efficiently than having the person move livestock when walking around the outer perimeter of the round crowd pen.

An inside radius of 5 m is ideal for cattle (additional recommendations are given in Grandin and Deesing, 2008). Walkways for the handler should run alongside the race, and the use of overhead walkways should be avoided. In slaughter plants with restricted space, a serpentine race system can be used (Grandin, 1984). A race system at an abattoir must be long enough to ensure a continuous flow of animals to the stunner, but not be so long that animals become stressed from waiting in line too long. A hold-down rack over the top of a single file race must not touch the backs of the animals, as they tend to panic if hold-down bars press on to their backs.

Crowd pen design leading to single file

A well-designed round crowd pen takes advantage of the animal's natural tendency to want to go back to where it came from. As animals move through the round pen, they will think they are going back to the lairage (**Figs 6.6, 6.9**). The recommended radius of the crowd pen is 3.5 m for cattle, 2.5 m for pigs or sheep. A funnel-shaped transition works well to direct cattle and sheep into a single file; one side of the funnel should be straight and the other should be on a 30-degree angle. **Figure 6.9** shows the correct layout for cattle. Funnels work poorly

for pigs (Hoenderken, 1976). The entrance of the pig race should be abrupt (**Fig. 6.10**).

Unloading of trucks

Prompt unloading upon arrival at an abattoir is essential for good animal welfare. More than one unloading dock is strongly recommended. If animals have to be weighed or counted upon arrival, there should be an unloading pen for each unloading dock. These pens enable animals to be unloaded promptly prior to sorting, weighing or identification checking. After one or more procedures have been performed, the animals move to a holding pen in the lairage. Facilities used for unloading only should be 2.5–3.0 m wide to provide the animals with a clear exit into the alley (Grandin, 1980a).

A big problem in some developing countries is that there may be no unloading ramps. Animals are jumped out of vehicles and may break legs. Ramps can be easily built from either steel or concrete by local welders or masons. People skilled in welding and masonry are readily available in all developing countries. In most countries, two ramps will be needed: one for large trucks and one for smaller pickup ('ute') trucks. Stationary ramps are easier for local people to build than complicated devices such as hydraulic tailgate lifts or ramps that move up and down.

Ramps and slopes

Ideally, an abattoir should be built at truck deck level to eliminate ramps for both unloading and movement to the stunner. This is especially important for pigs. The maximum angle for non-adjustable livestock truck loading ramps should be 20–25 degrees. The ramp leading to the stunner should not exceed 10 degrees for pigs, 15 degrees for cattle

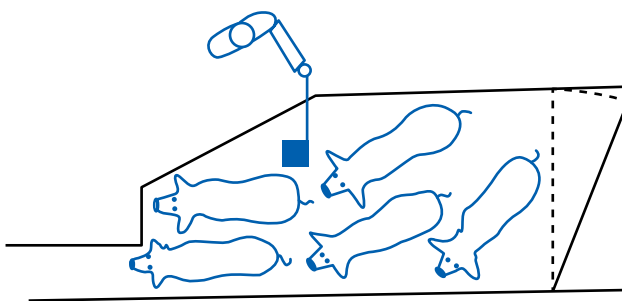


Fig. 6.10. The diagram shows a simple crowd pen design that has an offset step in the single-file race entrance which helps prevent jamming by allowing one pig to step aside. The handler is shown in the correct position to move pigs. The handler should work opposite to the straight edge. (From Grandin, 2015, p. 90.)

and 20 degrees for sheep. Ramp angles to the stunner should be more gradual than the maximum angles that will work for loading trucks. A loading ramp for pigs should not exceed 20 degrees (Warriss *et al.*, 1991). Pigs remain calmer on a ramp with a more gradual slope (Warriss *et al.*, 1991; Berry *et al.*, 2012). To reduce the possibility of falls, unloading ramps should have a flat deck at the top. This provides a level surface for animals to walk on when they first step off the truck. This same principle also applies to ramps to the stunner; a level portion facilitates animal entry into the restrainer or stunning box.

Grooved stair steps are recommended on concrete ramps (Grandin, 1980a, 2008) (Fig. 6.11). They are easier to walk on after the ramp becomes worn or dirty. The dimensions for cattle and other large animals are a 10 cm rise and a 30 cm or longer tread width. Steps 45 cm (18 in) long are recommended. For slaughter-weight pigs, cleats should be spaced 15 cm apart (Warriss *et al.*, 1991). For cattle, the spacing should be 20 cm of space between the cleats (Grandin, 2008). In pigs, there were very few differences in stress levels when they were loaded or unloaded with either a ramp or a hydraulic tailgate lift (Brown *et al.*, 2006). In developing countries, small livestock such as sheep may be handled manually during loading instead of using a ramp. Yardimci *et al.* (2012) reported that use of a ramp will reduce stress in sheep. Construction of a ramp is strongly recommended.

Handling systems for pigs

In Germany, Hartung *et al.* (1997) found that pigs were less stressed in a very short 3.5 m race than in a longer 11 m race. Figure 6.10 shows a crowd pen for pigs with an abrupt entrance. Funnel-shaped crowd pens work poorly with pigs. German plants run at slower speeds than plants in the USA and a race 3.5 m long may cause more stress in a plant running 800 pigs per hour, because the short race makes it more difficult to keep up with the line. In plants slaughtering 240 or fewer pigs an hour, stunning them with electric tongs in groups on the floor was less stressful than a double single-file race (Warriss *et al.*, 1994). In larger plants with a higher line speed, floor stunning with tongs tends to get rough and careless. In a small plant, pigs stunned in small groups on a floor had better meat quality (Stuier and Olsen, 1999).

In very small abattoirs where 20 or fewer market-weight pigs are processed per hour, some abattoirs use a captive bolt. The pigs are held in small groups of four to five animals in a small pen. The author observed that the other pigs had very little reaction when a pig was shot. Schaeperkoetter (2019) found that the last pig that was shot with a captive bolt was less stressed than the first pig in the group. The pen must have sufficient space so that the other pigs have sufficient space to move away. With a skillful stunning operator who seldom missed a shot, the other pigs did not squeal or become agitated. They

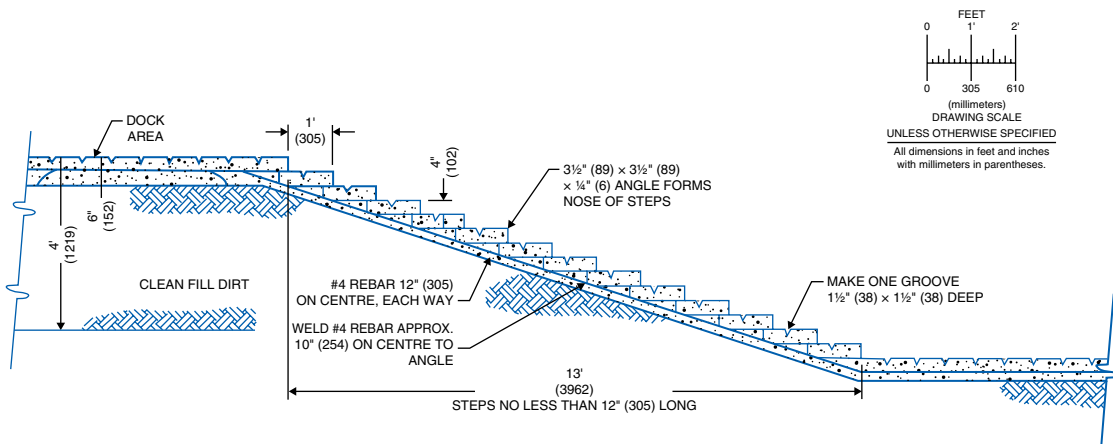


Fig. 6.11. For concrete ramps, stair steps are strongly recommended. One advantage of stair steps is that when they become worn, the animals can still walk easily on them. For unloading ramps, use 10 cm rise and 45 cm long tread length. The ramp has a level dock area so that animals exiting the truck will walk on a level floor. If cattle are wild, the level area should be 6 m (20 ft).

appeared to be unaware of what was happening. Anecdotal evidence suggests that the other animals should never observe the head being removed.

Group handling eliminates electric prods on pigs

Group handling systems for CO₂ stunning have significant advantages compared with handling pigs in single file races. Four to eight pigs at a time can be moved into the gondola and electric prods can be completely eliminated. Often the simpler systems with just a few powered pusher gates are better. Equipment companies like to sell many more powered pusher gates than are actually needed. The best systems have powered gates where a person can easily control forward movement. This prevents overcrowding of the pigs. Pigs must *never* be dragged or knocked over by powered gates. When vertical slide gates are used for pigs, injuries can be prevented by constructing the entire gate from a flexible piece of rubber conveyor or belting (Fig. 6.12). If the gate is closed on the pigs, the rubber flap will fold up.

Stun Boxes and Restrainers

Conventional stun boxes

A common mistake is to build stun boxes too wide. A stun box 76 cm wide will hold all cattle with the exception of some of the largest bulls. Stun boxes must have non-slip flooring to allow the animal to stand without slipping. A level or almost level floor is recommended. Stun boxes

with steeply sloped floors or stepped floors often cause animals to become agitated. Use of these floor designs should be avoided. In a conventional cattle stun box, stunning accuracy can be greatly improved by the use of a yoke to hold the animal's head. For cattle, yokes and mechanized head restraints are often used (Figs 6.1 and 6.2). Figure 6.13 shows an innovative stun box where a rear pusher gate has been eliminated. The headholder travels towards the animal instead of pushing the animal forward. Ewbank *et al.* (1992) found that cattle had higher stress levels when their heads were restrained. The system they observed was poorly designed and lacked a rear pusher gate. Forcing the animal's head into the restraint was difficult and took an average of 32 s. In well-designed systems, cattle will enter easily and the head is restrained within 5 s.

To minimize stress, the yoke must be designed so that the animal will enter it willingly (see Box 6.1). It must be stunned immediately after the head is caught. Munoz *et al.* (2012) and Paranhos de Costa *et al.* (2014) give additional information on correcting problems in stun boxes.

Restraint methods that cause suffering

The OIE (2019a,b) guidelines for animal welfare state that methods of restraint that cause avoidable suffering should not be used. Some of the worst methods that should never be used are:

- suspending or hoisting animals (other than poultry) by the feet or legs;



Fig. 6.12. Vertical slide gates constructed from flexible curtains made from conveyor belting will not injure the pigs if they are accidentally closed on them. (Photo courtesy of Temple Grandin.)

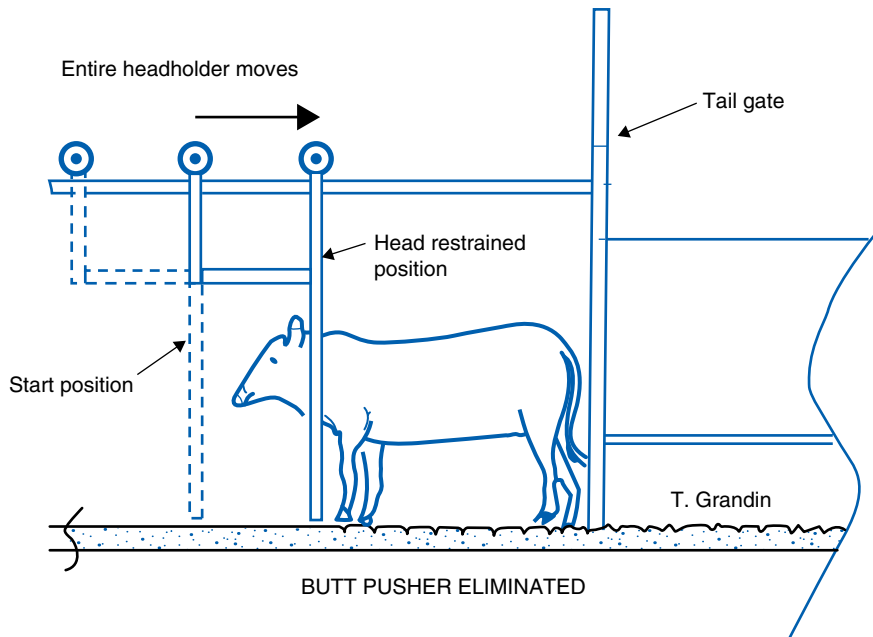


Fig. 6.13. This innovative stun box head yoke design eliminates the problems associated with pushing cattle forward with a rear pusher gate. The entire head yoke (headholder) assembly slowly moves backward towards the animal. Sudden jerky motion must be avoided. To block the animal's view of activity in front of the headholder, a solid shield should be installed in front of the headholder. (Diagram courtesy of Temple Grandin.)

- mechanical clamping of the legs of mammals;
- breaking legs or tails;
- cutting leg tendons;
- blinding by poking out eyes;
- severing the spinal cord with a puntilla (dagger) that paralyses the animals; and
- electrical immobilization with currents that are not sufficient to cause loss of sensibility (Lambooy, 1985; Grandin *et al.*, 1986; Pascoe, 1986; Rushen, 1986ab; Rushen *et al.*, 1986).

Conveyor restrainer systems

One advantage of conveyor systems is that animals follow their herdmates and will not have the stress of being alone (Bates *et al.*, 2014). One of the first modern systems was the 'V' conveyor restrainer for pigs (Regensburger, 1940). This consists of two obliquely angled conveyors that form a V. Pigs ride with their legs protruding through the space at the bottom of the V. The V restrainer is a comfortable system for pigs with round, plump bodies and for sheep (Grandin, 1980a). Pressure against the side of the pigs will cause it to relax (Fig. 6.14) (Grandin *et al.*, 1989). Both sides of the conveyor restrainer



Fig. 6.14. V conveyor restrainer for either pigs or sheep. The slats are constructed from insulating plastic for use with electrical stunning of either pigs or sheep. Both sides of the conveyor must run at the same speed to prevent animals from struggling. Photo courtesy of Temple Grandin.

must run at the same speed. Pigs may struggle or vocalize if one side runs faster than the other. However, the V restrainer is not suitable for restraining calves or extremely heavily muscled pigs with

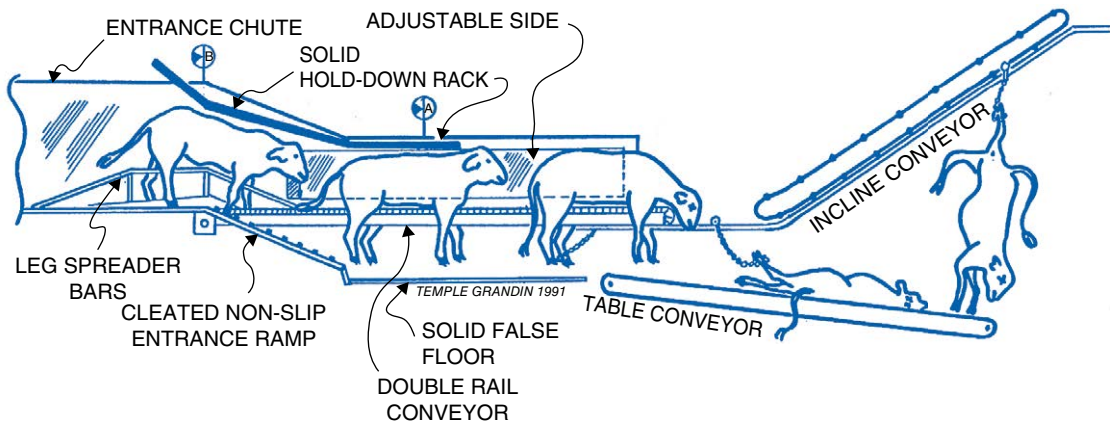


Fig. 6.15. Centre track double rail conveyor restrainer system for cattle. For cattle, it has many advantages compared with a V restrainer conveyor. (From Grandin, 1993, p. 303.)

large, overdeveloped hams (Lambooy, 1986). The V pinches the large hams and the slender forequarters are not supported. Some of the very lean, long pigs are also not supported properly by the V restrainer.

Researchers at the University of Connecticut, USA, developed a laboratory prototype for a double rail restrainer system to replace V conveyor restrainers (Westervelt *et al.*, 1976; Giger *et al.*, 1977). Calves and sheep are supported under the belly and the brisket by two moving rails. This research demonstrated that animals restrained in this manner were under minimal stress. Sheep and calves rode quietly on the restrainer and seldom struggled. The space between the rails provides a space for the animal's brisket and prevents uncomfortable pressure on the sternum. The prototype was a major step forward in humane restrainer design, but many components still had to be developed to create a system that would operate under commercial conditions.

In 1986, the first double rail restrainer was designed and installed in a large commercial calf and sheep slaughter plant by Grandin Livestock Handling Systems and Clayton H. Landis in Suderton, Pennsylvania, USA (Grandin, 1988). In the early 1990s, the Stork Company in the Netherlands developed a restrainer where pigs ride on a moving centre line conveyor.

In 1989, the first double rail restrainer was installed in large cattle slaughter plants by Grandin Livestock Handling Systems and Swilley Bond Equipment, Logan, Iowa, USA (Figs 6.14, 6.15) (Grandin, 1993). Half the cattle in North America are now handled in



Fig. 6.16. Large fed steer in the centre track double rail restrainer. The slats on the conveyor are shaped to fit the animal's brisket. Adjustable side panels move in and out to fit different sized cattle. (From Grandin, 1993, p. 303.)

this system, and it has been installed in over 30 plants. The double rail restrainer has many advantages compared with the V restrainer (Grandin, 1993) (Figs 6.15, 6.16). Stunning is easier and more accurate, because the operator can stand 28 cm closer to the animal. Cattle also enter more easily, because they can walk in with their legs in a natural position.

Proper design is essential for smooth, humane operation. Incoming cattle must not be able to see light coming up from under the restrainer. It must have a false floor below the restrained animal's feet, to provide incoming cattle with the

appearance of a solid floor to walk on (Grandin, 1993). To keep cattle calm, they must be fully restrained and settled down on the conveyor before they emerge from under the hold-down rack. If the hold-down is too short, the cattle are more likely to become agitated. The principle is to block the animal's vision until it is fully restrained (Grandin, 2003).

Solving problems in stun boxes and conveyor restrainers

If animals struggle, vocalize or become agitated in the stun box, non-stun slaughter box or conveyor restrainer, their welfare is not acceptable. The most common causes of these problems are described in Box 6.2.

Box 6.2. Solving problems in stun boxes and conveyor restrainers

Use this outline to locate and remedy problems that cause livestock either to refuse to move forward or to become agitated.

- **Distractions that cause baulking** – This was discussed in the first part of this chapter.
- **Stun box floor is slick** – The animal becomes agitated because its feet do numerous rapid small sideways slips. Observe the animal's feet from the shackle side of the box. A steel floor made from diamond-embossed steel is often not adequate to prevent slipping. It should have either steel rods welded to it or a rubber mat. Never crisscross the rods on top of each other. The rods must lie flat on the floor of the box.
- **Stun box floor jiggles** – A metal floor that jiggles may scare animals. Animals may refuse to enter the stun box when they see the jiggling floor.
- **Baulking at visual cliff** – In both V restrainer conveyors and the double rail (centre track) conveyor restrainer, incoming cattle, pigs or sheep must not be able to see that the conveyor is raised up above the floor. It must have a false floor below the restrained animal's feet to provide the appearance of a solid floor to walk on. Block light that comes up from underneath the conveyors.
- **Excessive pressure applied by a headholder or other restraint device** (Grandin, 1998, 2001; Bourguet *et al.*, 2011) – When there is excessive pressure, cattle or pigs will vocalize in direct response to being clamped in the device. The remedy is to reduce the pressure applied to the animal. Cattle vocalization is associated with higher cortisol levels (Dunn, 1990; Hemsworth *et al.*, 2011).
- **Holding an animal in the fully restrained position too long** (Velarde and Raj, 2016) – This is especially a problem in non-stun slaughter boxes. This may cause cattle to vocalize. The animal should be stunned immediately after its head is restrained.
- **Sharp edges or pinching of the animal hide by the equipment** – A very small sharp edge or pinching of the skin will cause the animal to struggle or vocalize.
- **Excessive electric prod use** – This may cause animals to enter the box or conveyor in an agitated state and make stunning difficult. Train employees and remove distractions that cause baulking.
- **One side of a V conveyor restrainer runs faster than the other** – This will cause struggling due to pulling and stretching of the skin.
- **Animal thrown off balance causes struggling** – Restrainers that hold the animal's body with a squeeze side must not tilt it off balance. In systems where an upright animal is supported with its feet off the floor, it must be held in a balanced position. Examples of properly designed systems are in Regensburger (1940), Giger *et al.* (1977), Panepinto (1983) and Grandin (1988, 1992, 1993).
- **Animal's body not fully supported in rotating boxes** – Cattle will struggle if their bodies slip when the box rotates. The body must be held snugly.
- **Poorly designed controls on hydraulic or pneumatic equipment** – Pneumatic systems should be designed to enable the operator to have mid-stroke position control of the air cylinders that operate headholders and other restraint devices (Grandin, 1992). This will enable the operator to use lighter pressure for smaller animals. Controls should also be designed to limit the maximum pressure that can be applied. For example, a headholder requires a much lighter maximum pressure setting than a heavy door. Separate pressure relief valves on different parts of the system will prevent a careless operator from injuring an animal with either a headholder or rear pusher gate. Avoid air being powered down on vertical doors at the entrance and exit of a stun box. The control system should be designed so that the operator can immediately stop a gate from moving. This will help prevent bruising at the stun box door. On poorly designed systems, that door may continue to move downward when the operator pushes the control to raise it. There is more information and design of controls in Grandin (1992, 2016).

Conclusions

Both good design of equipment and supervision of employees are required to have a high standard of animal welfare. Employees should be trained in the behavioural principles of livestock handling. Handling and welfare during handling and stunning can often be achieved after making simple improvements in facilities. Non-slip flooring in stun boxes and unloading areas is essential. Changing lighting or adding a light can be used to improve animal movement.

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7

Review of Scientific Research Studies on Poultry Stunning Methods

CHARLOTTE (LOTTA) BERG^{1*} AND MOHAN RAJ²

¹*Department of Animal Environment and Health, Swedish University of Agricultural Sciences, Skara, Sweden;* ²*Formerly Reader in Animal Welfare, Department of Clinical Veterinary Science, University of Bristol, UK*

Summary

In this chapter, we will list the most commonly used methods for the stunning of poultry and the welfare aspects in relation to each method. The detailed physiological mechanisms for most of the stunning methods described can be found in, for example, the European Food Safety Authority (EFSA) report on the welfare aspects of the main stunning methods used by slaughterhouses for stunning commercial species of animals used for human food (EFSA, 2004). Based on the scientific evidence, the European Commission (EC) has legislated (EC Slaughter Regulation 1099/2009) certain minimum standards for stunning and killing of animals, including poultry. Similarly, Office International des Epizooties (OIE), the world organization for animal health and welfare, has produced guidelines for stunning and slaughter of animals.

In general, humane slaughter regulations and guidelines have the following requirements.

- No conscious animal shall be shackled or hoisted. However, poultry species are exempted for practical reasons.
- Animals, including poultry, must be rendered immediately unconscious prior to slaughter and they should remain so until death occurs through blood loss.
- Both carotid arteries supplying oxygenated blood to the brain must be severed.

- Animals, including poultry, must be dead before carcass dressing (including decapitation) or any other treatment (e.g. electrical stimulation or scalding) is carried out.

Learning objectives

- Understand how electrical stunning of poultry works.
- Understand the welfare issues associated with water-bath stunning.
- Understand the relevant electrical specifications and different types of electrical stunning.
- Be familiar with the use of captive bolt in poultry.
- Be familiar with the use of different types of gases for stunning poultry.
- Be familiar with the principles of low atmosphere pressure stunning of poultry.

Introduction

Legislation in many countries worldwide requires that poultry, just like mammals, should be stunned prior to exsanguination (Lambooij and Hindle, 2018). The reason behind this is that rendering the birds unconscious means that they will not experience pain, distress or unnecessary suffering during the neck cutting and bleeding phase of slaughter. Successful application of a stunning method should lead to immediate onset of unconsciousness that lasts until death occurs by bleed-out.

* Email: Lotta.berg@slu.se

The duration of unconsciousness induced by a stunning method must hence be longer than the sum of the time that elapses between the end of stun and neck cutting and the time to onset of death following neck cutting (Raj, 2010; Lines *et al.*, 2011). Since the effect of a stunning method is momentary, the onus of preventing resumption of consciousness thereafter relies on the efficiency of the slaughter procedure, e.g. bleeding out by the prompt and accurate severance of carotid arteries supplying oxygenated blood to the brain. Some stunning procedures are therefore purposefully applied to induce humane death (e.g. killing with argon or nitrogen-induced anoxia, electrocution via head-to-body electrical stunning), rather than mere unconsciousness, and other methods lead to death due to structural damage to the brain (e.g. penetrating captive bolts) (Raj, 2010).

This chapter will also include some comments on the most commonly identified animal welfare problems in relation to each method and possible ways of minimizing these welfare risks. Furthermore, EFSA is currently updating its scientific review on slaughter of poultry, with a focus on animal welfare hazards, and a report has recently been published on the EFSA website (EFSA, 2019).

The methods dealt with in this chapter are electrical water-bath stunning, head-to-body dry electrical stunning, head-only electrical stunning, penetrating and non-penetrating captive bolt stunning, two- and multistage carbon dioxide stunning, exposure to inert gases with or without added carbon dioxide and low atmospheric pressure stunning. This covers the vast majority of the commercial broiler slaughter taking place globally. Broilers are by far the most common type of meat-producing poultry and in many cases the methods applied for broilers can be – and are – also used for stunning other types of poultry, such as end-of-lay hens, turkeys, ducks, geese and so on.

Electrical Water-bath Stunning

Mode of action

Electrical water-bath stunning is by far the most common stunning method used worldwide not only for broiler chickens but also for other types of poultry.

The brain mechanism behind electrical stunning is that application of a current of sufficient magnitude to the brain will induce a generalized epileptiform

activity and associated seizures; and this abnormal brain state is incompatible with the persistence of consciousness (Lambooy, 1981; Raj, 2006; Raj *et al.*, 2006a,b; Lambooy and Hindle, 2018). Multiple-bird electrical water-bath stunning is the most common and cheapest method of rendering poultry unconscious prior to slaughter under commercial conditions, where high throughput rates are required (Raj, 2010). In this system, conscious birds are hung upside-down on a moving metal shackle line and passed through an electrified water-bath, such that the current flows through the whole body towards the shackle (to the earth). This means that the entire bird is part of the electrical circuit (Raj, 2004).

Depending on the electrical parameter settings, water-bath stunning can be either reversible or irreversible. Exposure of poultry to low-frequency currents (e.g. less than 100 Hz) will lead to cardiac arrest via the induction of cardiac ventricular fibrillation, which would eliminate the risk of recovery of consciousness following stunning (Schütt-Abraham *et al.*, 1983). Ventricular fibrillation can usually be achieved by delivering 120 mA per bird (for broilers) in a water-bath supplied with a 50 Hz sine wave alternating current (AC) (Berg and Raj, 2015). If higher frequencies are applied, it is usually not possible to achieve cardiac arrest in the birds, and hence the birds will recover consciousness if not immediately bled after stunning. The electrical requirements for poultry water-bath stunning have been reviewed by EFSA, with a focus on the time to induce unconsciousness and the duration of unconsciousness once achieved (EFSA, 2014b).

Animal welfare aspects of electrical stunning

From an animal welfare perspective, there are four main problems related to water-bath stunning of poultry:

- the inversion and shackling of conscious birds, which is an inevitable component of water-bath stunning;
- pre-stun shocks at the entrance to the stunners;
- the fact that several birds are stunned at the same time, and each receives a different amount of current inversely proportional to their electrical resistance; and
- the limited duration of unconsciousness induced.

Inversion and shackling are carried out as a restraining method to facilitate immersion of birds' heads in the water-bath (Fig. 7.1). Inversion in itself



Fig. 7.1. Inverted shackling of conscious birds is an unavoidable animal welfare problem related to poultry water-bath stunning. (Photo courtesy of C. Berg.)

is considered stressful (Kannan and Mench, 1996, 1997), and birds have pain receptors in their legs (Gentle and Tilston, 2000). Hence, birds will experience distress and pain when shackled. Bedanova *et al.* (2007) reported that the duration of shackling (i.e. birds hanging on shackles) was positively correlated with plasma corticosterone, glucose and lactate levels, tonic immobility duration and heterophil:lymphocyte ratio in broilers. Shackling has been considered as a major welfare issue associated with water-bath stunning of poultry (Sparrey *et al.*, 1992; Sparrey, 1994; Lambooij and Hindle, 2018). It has been reported that 90% of chickens start flapping their wings immediately after shackling and that this lasts on average for 14 s (Kannan and Mench, 1997). Wing flapping is triggered subsequently by several factors. In particular, in cases where shackle design is poor, breast support plates are absent or the birds are handled in a rough way during shackling, or jolts or vibration occur in the shackle line due to poor design, construction or maintenance, birds may start flapping their wings considerably between the point of shackling and reaching the water-bath (AVMA, 2016). Owing to the welfare concern, the duration between shackling and stunning is limited in the EC slaughter regulation to 1 min for broilers and 2 min for turkeys. By ensuring that staff are well trained (Berg, 2012) and are handling the birds carefully, and by using correctly designed

shackles of an appropriate size for the bird, by installing appropriate breast comfort plates and by applying a short interval from shackling to stunning (Lambooij and Hindle, 2018), these problems can be mitigated to some extent, but never completely. For heavy birds, such as turkeys, the shackling-related animal welfare problems are considered to be worse than in chickens. Dimming of lights or using blue light in the shackling area has been known to have a calming effect on birds and reduce wing flapping.

If birds are wing flapping as a result of pain or distress at shackling, because of long shackling lines (resulting in a long time interval from shackling to the water-bath entrance) or if the water-bath entrance is poorly constructed, birds may encounter electrical contact with the water-bath with the wings prior to the head. This will result in painful pre-stun electric shocks (Berg and Raj, 2015). Turkeys' wings hang lower than their heads and, owing to this, are predisposed to receiving pre-stun shocks at the entrance to the water-bath stunners.

Problems with variations in electrical resistance

In multiple-bird water-bath stunning systems, birds are constantly entering and leaving the water-bath with changing electrical resistance in the circuit. The electrical flow through each individual bird will be dependent on the resistance in the pathway for that particular bird. The effective electrical resistance can vary between birds, for example, between 1000 and 2600 ohms in broilers and between 1900 and 7000 ohms in layer hens (Schutt-Abraham *et al.*, 1987; Schutt-Abraham and Wormuth, 1991). Where water-bath stunners are supplied with constant voltage, birds with low electrical resistance will receive more current than necessary to achieve effective stunning, whereas those with high resistance will receive less current than necessary to achieve effective stunning. Birds in the former category will have good welfare outcome at stunning but could have poor carcass and meat quality, whereas the latter category will have poor welfare outcome and good meat quality. Most of the electrical resistance in the pathway is attributed to the poor contact between the legs and the metal shackle. The implication of this is that tighter shackle–leg fitting will reduce the electrical impedance, but this will have the negative effect of

increased suffering due to pain. Nevertheless, routine cleaning of shackles using appropriate detergent to remove accumulation of fat and dirt and wetting the shackles prior to hanging live birds would help to improve electrical contact and minimize electrical resistance.

Although poultry flocks are often reasonably even in size and conformation, there is always some variation in size, weight, plumage condition, cleanliness or electrical contact between the legs and the metal shackle, and multiple-bird water-bath stunners supplied with a constant voltage will therefore not deliver effective stunning currents to all birds in the water-bath (Sparrey *et al.*, 1992; Hindle *et al.*, 2010) (Fig. 7.2). This is even more explicitly stated by EFSA, where a 2014 report stated that the electrical resistance varies widely between birds, making it impossible to deliver the same constant and predetermined current to each individual bird. Furthermore, EFSA stated that ‘the complexity of such multiple-bird electrical water-bath stunning systems used in poultry slaughterhouses is not conducive to maintaining good animal welfare and, therefore, alternatives should be developed/implemented’ (EFSA, 2014b).



Fig. 7.2. Due to variations in bird size, weight etc., multiple-bird water-bath stunners are unable to deliver the same predetermined current to each individual bird. (Photo courtesy of C. Berg.)

Reversible or irreversible stunning?

Although it is well known that a combination of high current (e.g. 120 mA) and low frequency (< 100 Hz) can be expected to result in cardiac arrest and death in the birds, and hence eliminate the risk of birds regaining consciousness before or during bleeding, many slaughterhouses do not use these electrical setting parameters. The reason for this is mainly related to product quality, as high-frequency stunning results in fewer problems with blood splash or fractures, which may lead to downgrading or rejection of the meat (Wilkins *et al.*, 1998; Kranen *et al.*, 2000) or to religious requirements (Sabow *et al.*, 2017; Lambooi and Hindle, 2018). Hence, reversible stunning parameters are often used, which means that the stun-to-stick/cut interval must be kept to an absolute minimum. Globally, a large number of different settings are used commercially, not only with reference to current levels (amps) and frequencies (Hz), but also for waveforms (AC or DC) (Hindle *et al.*, 2010; EFSA, 2013), sometimes without full understanding of how these parameters relate to each other and how the settings affect the stun quality of the birds. Indeed, electrical immobilization of conscious birds for the purpose of automatic neck cutting could not be excluded, in the worst-case scenario, especially when using low currents and high frequencies. Research has shown that sine or square wave alternating current is more effective than pulsed direct current, low frequencies (< 800 Hz) are more effective than high frequencies and that the minimum current necessary to achieve effective stunning increases as frequency of the current is increased (Raj, 2006). Girasole *et al.* (2016) evaluated electrical water-bath stunning of broilers with an average root mean square (RMS) current of 150, 200 and 250 mA and frequencies of 200, 400, 600, 800 and 1200 Hz. In this study, occurrence of corneal reflex, spontaneous eye blinking and a positive response to a painful stimulus were monitored and recorded immediately after the stunning and at 20 s post-stun during bleeding. The results clearly indicated that, at a current of 150 mA, the probability of a successful stun was over 90% at 200 Hz, approximately 40% at 400 Hz and below 5% for frequencies greater than 600 Hz. Therefore, the authors concluded that stunning at frequencies greater than 600 Hz cannot be recommended when RMS current of 150 mA is applied. The maximum probability of achieving a successful

stun required a current level of 200 mA at 400 Hz and a current level of 250 mA at 400 and 600 Hz, whereas the stunning treatments at 1200 Hz provided the lowest probability of a successful stun.

There are additional welfare concerns associated with water-bath stunning of ducks and geese. Firstly, heads of these poultry species are not always immersed in the water-bath; instead, the base of the neck or crop makes contact with the water (Humane Slaughter Association, 2015). This is because the birds bend their necks backwards, known as swan necking (Fig. 7.3).

The duration of reversible stunning is often limited, and hence prompt and accurate cutting of both carotids is essential to avoid the risk of birds regaining consciousness during bleeding or remaining alive whilst entering the scald tank.

A novel method of electrical water-bath stunning of individual birds has been developed for commercial use at broiler slaughter (Berg and Raj, 2015). In this system, birds are shackled as under the conventional water-bath stunning systems, but each bird is lowered into a separate water-bath and the body electrode is placed on the vent (Lambooij



Fig. 7.3. Ducks and geese tend to lift their heads by bending their necks backwards; hence there is a risk that the base of the neck or crop makes contact with the water first. (Photo courtesy of M. Raj.)

et al., 2008, 2012). This means that each individual bird has its own water-bath, and hence the electrical parameters are not influenced by the impedance of other birds. Avoiding leg-to-shackle contact, which is the main source of electrical resistance in the circuit, is innovative and it may help to reduce the amount of voltage necessary to deliver the minimum current required to achieve effective stunning and killing.

Head-only Dry Electrical Stunning

Mode of action

There are commercial systems available for head-only electrical stunning of poultry using dry electrodes. One such system is built on the principle of restraining the bird in an inverted position in a cone and electrodes are automatically placed on each side of the head for stunning (Lambooij *et al.*, 2014) (Fig. 7.4). In this way, a constant current can be applied to each bird (Berg and Raj, 2015). There are also commercial systems available with a less automated approach for small-scale slaughter of broilers, hens, turkeys or other types of poultry, where each bird is restrained manually and positioned horizontally in contact with the two metal electrodes on each side of the bird's head (Berg and Raj, 2015).

Research has shown that, when using sine wave alternating current to deliver a constant current, the effectiveness of head-only electrical stunning



Fig. 7.4. Dry electrical stunning with manual restraint of the bird. (Photo courtesy of C. Berg.)

depends upon the frequency and amount of current delivered to individual birds (Raj and O'Callaghan, 2004). Based on the results, the authors concluded that minimum currents of 100, 150 and 200 mA should be delivered whilst using 50, 400 and 1500 Hz, respectively, to achieve adequate depth and duration of unconsciousness in broilers (Raj, 2004).

Animal welfare aspects of head-only stunning

From an animal welfare point of view, head-only electrical stunning system can deliver the required electrical current to an individual bird, if properly set up and managed. However, it only produces a reversible stun, often limited, and hence rapid cutting of both carotids is essential to avoid the risk of birds beginning to regain consciousness, i.e. the same issue as for reversible electrical water-bath stunning discussed above.

Penetrating and Non-penetrating Captive Bolt

Mode of action

A penetrating captive bolt can be used for stunning any species of poultry; however, it is used at commercial slaughterhouses as a back-up method. It is an option for small-scale slaughter or slaughter for private domestic consumption. Cartridge-powered, pneumatic (compressed air) and spring-operated captive bolts are available on the market (Raj and O'Callaghan, 2001; Gibson *et al.*, 2018) (Fig. 7.5). It has been suggested that the appropriate variables



Fig. 7.5. An example of a cartridge-powered captive bolt gun for any size and type of poultry. (Photo courtesy of C. Berg.)

for captive bolt stunning of broilers are a minimum of 6 mm bolt diameter driven at an air-line pressure of 827 kPa and a penetration depth of 10 mm (Raj and O'Callaghan, 2001).

To achieve effective stun, it is important that the bolt is correctly positioned (perpendicular to the skull), of sufficient width and penetration depth (if penetrating), and that the energy transmitted is sufficient (Raj and O'Callaghan, 2001; Martin *et al.*, 2019). Experience shows that spring-operated captive bolts do not necessarily meet these requirements and risk resulting in an insufficient stun. However, cartridge-powered, compressed air-powered and propane fuel cell-powered stun guns can consistently produce an effective stun, i.e. immediate insensibility, also in large birds such as turkeys (Erasmus *et al.*; 2010a,b; Gibson *et al.*, 2018; Woolcott *et al.*, 2018).

Animal welfare aspects of captive bolt stunning

In relation to animal welfare, the main risks related to the use of captive bolt guns are improper restraint of the bird, applying the bolt at an incorrect angle and using a bolt with too narrow diameter and/or too low velocity, all resulting in an insufficient stun. For example, Raj and O'Callaghan (2001) reported that when the captive bolt was shot at 110°, 120° or 130°, the majority of birds survived, continued breathing and showed no convulsions. Neck muscle tension and eye reflexes were also retained in these birds from the end of stunning. Post-mortem examination of the birds that survived after non-perpendicular shooting of the bolt revealed that the bolt either punctured a hole through the skin and skidded along the surface of the skull or only the rim of the bolt made contact with the skull, resulting in a compressed fracture. In the same study, examination of the skulls of broilers that were shot with a 3 mm bolt revealed that the bolt had penetrated the skull even though it failed to induce a stun. Evaluation of the spontaneous electroencephalogram (EEG) and visually evoked potentials (VEPs) indicated that these neurophysiological parameters also remained as that of pre-stun. This is because the crucial physical variable in determining the effectiveness of captive bolt stunning is the change of impulse per unit of time or, in other words, the product of mass and acceleration of the head upon the impact of the bolt. According to this, the maximum acceleration of the skull

would be expected when the mass of impacting projectile is at least equivalent to that of the head and the velocity is high. By contrast, a projectile with a very small mass and a very high velocity will result in an ultra-short time span in which the skull as a whole will hardly move during transfer of energy. Instead, during impact there will be a high transfer of momentum and energy locally, resulting in perforation of the skull without acceleration of the head (Karger, 1995). In this situation, penetration of a narrow bolt into the brain tissue may not always produce immediate loss of consciousness.

Various types of novel mechanical devices

Erasmus *et al.* (2010a) evaluated the effectiveness of a commercially manufactured (Zephyr), pneumatically operated (air-line pressure of 758–827 kPa) non-penetrating captive bolt (25mm diameter, 17 mm protrusion beyond the barrel) for on-farm euthanasia of turkeys and compared it with blunt force trauma, manual cervical dislocation and mechanical cervical dislocation (crushing of the neck) using a burdizzo (a neck-crushing device originally intended for crushing spermatic cord). The results indicated that the Zephyr device and blunt trauma were effective in causing immediate unconsciousness. In contrast, neither method of cervical dislocation caused immediate unconsciousness. Several studies have shown that cervical dislocation induced by neck crushing or brain piercing does not lead to immediate unconsciousness (Erasmus *et al.*, 2010b; Martin *et al.*, 2016, 2017) and therefore is not considered to be humane.

Martin *et al.* (2019) examined three novel mechanical killing devices: Modified Armadillo (MARM, a brain-piercing device), Modified Rabbit Zinger (MZIN, a penetrating captive bolt device, 6 mm in diameter, 2.5–3.5 cm penetration depth), a novel mechanical cervical dislocation device (NMCD, a mechanical method that closely resembled the manual cervical dislocation technique) and traditional manual cervical dislocation (MCD). Post-mortem examination was carried out immediately after confirmation of death in all the chickens in order to establish treatment-specific post-mortem lesions. The percentage incidence of successfully causing death was MCD = 100.0%, NMCD = 96.0%, MZIN = 75.0% and MARM 48.7%. However, whether application of these methods produced immediate unconsciousness in all the birds is not reported.

Exposure to Gas Mixtures

Mode of action

Gas stunning systems are often referred to as controlled atmosphere stunning (CAS), if reversible, or controlled atmosphere killing (CAK), if irreversibly rendering the bird unconscious (Thaxton, 2018). In general, exposure to gas mixtures leads to a gradual loss of consciousness in the birds and is considered a suitable method not only for broilers, laying hens and turkeys, but also for ducks and geese.

There are a number of different systems commercially available using gas mixtures to stun poultry. The gas mixtures can be carbon dioxide (in two or several phases), carbon dioxide in combination with inert gases, or systems based primarily on inert gases (see below).

There are different designs of gas stunners. Some are horizontal and placed on the floor, where the birds are taken through the system (on a conveyor belt with or without the original transport containers) at two or more levels (Gerritzen *et al.*, 2013) (Fig. 7.6). Others are of a deep-pit design, i.e. constructed as a deep hole in the floor, where a paternoster system or a lift system brings the containers down into the higher concentration of carbon dioxide, and then up again (Fig. 7.7). The unconscious birds are then shackled prior to neck cutting. Depending on the concentration of carbon dioxide and the duration of the exposure to the higher concentrations of the gas, the duration of unconsciousness induced will vary (EFSA, 2013). If the concentration is high enough and the duration of exposure long enough,



Fig. 7.6. A type of carbon dioxide stunning system where birds are first removed from the transport container, then taken on a conveyor belt through the two-stage carbon dioxide system, and finally shackled when unconscious. (Photo courtesy of C. Berg.)



Fig. 7.7. The shackling station at a multi-stage carbon dioxide system where the birds are stunned in their transport containers and shackled after becoming unconscious. (Photo courtesy of C. Berg.)

the stunning method will be irreversible, i.e. the birds will never resume breathing. Nevertheless, when birds are stunned using carbon dioxide or other gases in the context of slaughter, stunning should always be followed by bleeding. When birds are gas-stunned in groups, i.e. in their transport containers, the stunning duration has to be long enough to allow for shackling and bleeding of all the birds in that batch, before there is any risk of birds returning to consciousness.

Animal welfare aspects of gas stunning

The main advantage of gas stunning, from an animal welfare point of view, is that the birds do not have to be manually handled or shackled while conscious. Instead, the birds are stunned while sitting on a conveyor belt or still in their transport containers, eliminating the issue of removing the birds from the modules without causing injury. Shackling of freshly stunned birds can be performed in a well illuminated area; this and lack of wing flapping during shackling improves workers' health and safety.

Exposure to carbon dioxide

In the carbon dioxide stunners, the gas is administered in two or more phases (Meier *et al.*, 2015).

Birds are initially exposed to relatively low concentrations of CO₂ (less than 40%). Once the birds are unconscious, they are exposed to high concentrations of CO₂, typically 80–90% by volume in air (Berg and Raj, 2015). This process can, of course, be divided into more phases, where the CO₂ concentration is increased in smaller steps. The reason for gradually increasing the concentration of CO₂ instead of abruptly exposing the birds to high levels of the gas is that CO₂ is aversive, i.e. unpleasant to inhale. Both mammals and birds have chemoreceptors sensitive to CO₂ and therefore they will suffer pain and distress if exposed to high levels while still conscious (McKeegan *et al.*, 2006; Raj, 2006; Sandilands *et al.*, 2011; Berg *et al.*, 2014).

The main drawback from a bird welfare point of view is the aversiveness of CO₂ (Thaxton, 2018). Carbon dioxide is an acidic gas and is pungent to inhale (Raj and Tserveni-Gousi, 2000). Owing to this, chickens and turkeys, given a free choice, refuse to enter a feeding chamber containing high concentrations of CO₂ (Raj, 1996; McKeegan *et al.*, 2003; Sandilands *et al.*, 2011). Carbon dioxide is also a potent respiratory stimulant and therefore inhalation of this gas at any concentration will lead to respiratory distress prior to the onset of

unconsciousness. By recording the firing rate of trigeminal nerve fibres and behavioural responses (avoidance tests) to inhalation of CO₂ in chickens, McKeegan *et al.* (2003) demonstrated that 11% by volume of CO₂ in air substantially increased the rate of firing and chickens certainly avoided an atmosphere containing 24% by volume of CO₂ in air. However, it can also be argued that the pain and distress associated with the induction of unconsciousness with a high concentration of CO₂ for a brief period, for example 30 s, can be less than the cumulative pain and suffering associated with the live bird handling and electrical water-bath stunning.

When CO₂ stunning is used, the gas concentration at relevant locations in the chamber should be monitored and maintained continuously, as should the exposure time. The gas may need humidification and under no circumstances must dry ice be used, as dry gas may cause severe irritation.

Exposure to inert gases, with or without added carbon dioxide

Inert gases, such as nitrogen or argon, can be used to stun poultry, sometimes in combination with CO₂. Exposure of birds to inert gases containing less than 2% by volume of oxygen leads to hypoxia, which renders them unconscious. Inert gases are not aversive to birds (or other animals), and the birds will hence not display head-shaking or gasping when coming in contact with the gas, which would make these gases more suitable for stunning purposes than CO₂ at high concentrations. For example, research has shown that chickens and turkeys do not show any aversion to the initial exposure to or inhalation of 90% argon in air with less than 2% residual oxygen (Raj, 1996; Sandilands *et al.*, 2011). Webster and Fletcher (2001) showed that the behaviour of birds during exposure to argon was very similar to those exposed to atmospheric air, until the birds in argon lost consciousness.

However, hypoxia results in other types of negative effects, such as convulsions (wing flapping) after the loss of consciousness, which may be aesthetically unpleasant. In this regard, Ernsting (1965) reported that, under anoxic conditions, depression of activity in the mammalian brain extends progressively from the telencephalon to the diencephalon and then to the

mesencephalon. Anoxic convulsions result from the release of the caudal reticular formation from the suppression by higher centres, particularly the cerebral cortex and rostral reticular formation (Dell *et al.*, 1961; Ernsting, 1965). The implication of this is that the onset of anoxic convulsions themselves can be used as an indicator of the loss of consciousness (Raj, 2004, 2010; Raj and Tserveni-Gousi, 2000).

Low Atmospheric Pressure Stunning (LAPS)

Mode of action

Low atmospheric pressure stunning (LAPS) is a reasonably new technology, which is currently commercially approved by USDA (Vizzier, 2015) and by the European Union for broiler chickens weighing up to 4 kg (European Commission, 2018) after evaluation by EFSA (EFSA, 2014a, 2017). However, it is not currently used commercially.

According to the manufacturers, LAPS involves exposure of birds in transport containers to hypoxia created by removal of air via gradual decompression in two phases. In the first phase, a relatively rapid reduction in pressure from standard sea level atmospheric pressure of 760–250 Torr is achieved in 50 s. In the second phase, the pressure is reduced to 160 Torr over a period of 210 s (McKeegan *et al.*, 2013).

Animal welfare aspects of low atmospheric pressure stunning

The practical experiences from the LAPS system in relation to animal welfare are still limited, but the system shares the advantages of gas stunning systems by not having to shackle conscious birds. Time to reach the desired pressure should be monitored, as too rapid decompression is not acceptable on bird welfare grounds, and also temperature and humidity are of relevance (Holloway and Pritchard, 2017).

However, exposure of birds to LAPS results in other types of negative effects, such as convulsions (wing flapping) after the loss of consciousness, which may be aesthetically unpleasant. LAPS leads to irreversible stunning, i.e. when correctly carried out, birds will not regain consciousness.

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8

Stunning Poultry with Controlled Atmosphere Systems

TEMPLE GRANDIN*

Department of Animal Science, Colorado State University, USA

Summary

A major advantage of controlled atmosphere stunning (CAS) or low atmospheric pressure stunning (LAPS) for poultry is that it eliminates handling of individual live birds at the slaughter plant. These systems are currently being used for both broiler chicken and turkeys. Research clearly shows that shackling of live birds is highly stressful (Kannan *et al.*, 1997; Bedanova *et al.*, 2007). When modern CAS systems are used, the birds are stunned in the same containers that were used to transport them to the abattoir. There are systems available that can handle birds in single drawers, small coops, decks or large modules that have multiple compartments. Chickens should not be exposed to greater than 40% CO₂ until they have loss of posture (LOP) and become unconscious. After the birds are rendered unconscious and killed, they are removed from the transport container. At this point, the dead birds are hung on the shackles by people, bled and processed in the conventional manner. The most common operational mistake is speeding up a system to increase poultry productivity. This may have serious detrimental effects on bird welfare. CAS and LAPS systems must be operated according to scientifically validated parameters. Specifications for gas concentrations, air withdrawal rates and exposure times must be strictly followed.

Learning Objectives

- Learn how controlled atmosphere stunning works.
- Learn differences between poultry handling systems.
- Monitoring bird behaviour for welfare during induction of unconsciousness.

- Understand common commercial systems.
- Solve common operational problems.

CAS and LAPS Solve a Big Management Problem

The implementation of controlled atmosphere stunning (CAS) and low air pressure atmospheric stunning (LAPS) is one of the few areas in animal handling where a piece of equipment can eliminate the need for management supervision of employee behaviour. All the problems of bad employee behaviour and the possibility of bird abuse during live shackling are eliminated. There are numerous animal activist videos online of people throwing, kicking, stomping on or hitting live broilers and turkeys. With CAS, the people are now removed from live bird handling. Mishandling of dead birds is not a welfare issue. The author has done welfare audits and auditor training at many poultry slaughter plants. In some facilities, poor supervision of employees handling of live birds was a major issue. From a welfare perspective, [Table 8.1](#) compares electrical stunning with CAS or LAPS. It is essential that the transport containers are not overloaded. For all species of poultry, the birds must have sufficient space so that they can all lie down at the same time without being on top of each other. CAS systems are becoming increasingly popular. Raj (2017) reported that CAS is used on 60–65% of the broiler chickens in the UK and Germany. In Germany, 40% of the turkeys are stunned with CAS. The turkey industry in the USA is also increasing its use of CAS.

To maintain a high level of bird welfare, the CAS or LAPS process must be closely monitored. Supervision of

* Email: cheryl.miller@colostate.edu

Table 8.1. Welfare comparison of electrical versus controlled atmosphere stunning.

Stunning method	Advantages	Disadvantages
Electrical ^a	Instantaneous insensibility (Raj and O'Callaghan, 2004).	Birds are hung live inverted on the shackle line. This is stressful for the birds and increases plasma corticosterone (Kannan <i>et al.</i> , 1997; Bedanova <i>et al.</i> , 2007). Small birds mixed with large birds miss the water-bath and may not be stunned. Supervising and training employees is more difficult. Problems with people abusing birds are more likely because people handle each individual live bird. In poorly designed systems, the birds may get small pre-shocks before they enter the water bath.
Gas or low air pressure (LAPS)	Birds do not have to be removed from the transport containers for stunning. This greatly reduces handling stress. All birds in the container will be stunned. Less likely to have problems with employees abusing birds because they do not handle live birds.	Insensibility is not instantaneous. The distress and discomfort to the birds prior to the loss of insensibility will vary depending on the gas mixture or the speed of air removal. Requires very careful continuous monitoring of the gas mixtures. Wind around the plant building, changes in plant ventilation and opening and closing doors may change gas mixtures in some systems. These problems do not occur in LAP systems or closed gas systems. Much higher cost to install equipment compared with electrical stunning.

^aElectrical stunning takes place in a water-bath

employee handling of live birds is eliminated, but it now has to be replaced by management attention to details of the stunning process. Specifications for timing, gas mixture and other parameters must be closely followed.

How CAS and LAPS Systems Handle Birds

Controlled atmosphere stunning uses automated systems to move transport containers into the CAS chamber. There are three basic types of transport container movement systems (Box 8.1). In all these systems, a forklift is used to put a large module containing the birds on an automated module handling system. In all the systems, dead chickens or turkeys are hung on shackles after they emerge from the stunner.

How CAS and LAPS Systems Work

There are three basic methods that are used to control gas mixtures. They are outlined in Box 8.2.

Is a Deep Pit Required?

The most modern poultry CAS machines do not require an expensive deep pit constructed from reinforced concrete. The largest pork CAS systems do require an

expensive pit. Some older poultry CAS systems have a deep pit. The newest systems can be easily mounted on a concrete slab at plant floor level. No digging or concrete forming is required. This also provides a safety advantage for people performing maintenance.

The Most Common Operational Problems with CAS or LAPS System

The number one problem which can cause poor bird welfare in any CAS or LAPS system is having an undersized machine. When the line speed exceeds the capacity of the machine, managers are tempted to speed up the process of induction of unconsciousness. This will result in poor welfare and bird suffering. When poultry CAS equipment is being purchased, it is strongly recommended to obtain a machine that has sufficient capacity for increased future production. This will enable a business to grow without compromising bird welfare. When CAS systems are speeded up and fail to follow scientifically validated exposure times, gas mixtures and gas concentrations, the birds will suffer.

Compared with electrical water-bath stunning, CAS systems require more maintenance and more highly trained technical people to maintain and calibrate them.

Box 8.1. Transport container movement systems

- **Entire module systems** – An entire dump module or drawer module containing multiple bird compartments is placed on a conveyor table by the same forklift that was used to remove it from the truck. The birds are not touched by people until dead birds emerge from the stunning system. Entire module systems are often the best choice for large poultry plants that want to continue using their existing transport systems. This handling system is used with both CAS and LAPS.
- **Single drawer systems** – A module with multiple drawers containing birds is moved from the truck to an automated conveyor table by a forklift. Automatic equipment slides each individual drawer out of the module and moves it to a conveyor that goes into the CAS chamber. Single drawer systems require less floor space compared with entire module systems. This handling system is only used for CAS.
- **Live dump then move to CAS system** – This is an older style of CAS equipment that is being phased out when new abattoirs are built. In this system, live birds are dumped out and moved to a small conveyor that moves them through the CAS stunner. From a welfare standpoint, this system is inferior to the other systems because live birds are handled. It does eliminate live shackling. The main advantages of this system are that it often requires less floor space and that controlling the correct gas concentrations and mixtures is easier in a smaller chamber. It may be easier to install this system in an existing abattoir that is converting dump module electrical stunning to CAS. This would be especially true if floor space was limited or if there is not sufficient land for plant expansion. This handling system is only used for CAS.
- **Stacked deck modules** – This system has some definite advantages and may be a good choice for new poultry plants. It is not compatible with

the systems described above. New modules and vehicles will be required. In both conventional drawer and dump module systems, there are three separate compartments on each deck. In a stacked deck system, there is one large compartment on each deck. During unloading at the plant, each deck is removed from the stack and moved through the CAS stunner like a giant drawer. There is no rack like a conventional drawer system, because the framework for the rack is built into each stackable deck. Automated equipment removes each deck from the bottom of the stack. The large decks move through the CAS stunner with multiple stations in the same manner that conventional drawers are moved (Fig. 8.1). Each deck stops in each CAS station. Out on the farm, a module is formed with four stacked decks. The four stacked decks are the same size as a conventional drawer module with multiple compartments. The bottom deck has holes for the forklift and the fourth deck on the top of the stack has a retractable plastic cover. To ready the stacked decks for poultry loading, the floor of each deck is slid open. The floor consists of several sliding panels that overlap each other when they are slid open. The bottom deck is loaded first. When it is full, the floor of the next deck is slid shut over it. This forms both a cover for the bottom deck and a floor for the next deck. This process is repeated for the other three decks. This system provides advantages from a welfare perspective because it is much easier to load birds into the large wide decks. The stacked decks are loaded into the transport vehicle with a conventional forklift. Since the four decks are stacked like shipping containers, the truck has a hydraulic roof which lowers and presses down on all the stacked decks (Fig. 8.2).

Monitoring Induction of Unconsciousness

Looking at meters is not a substitute for observing the birds during the induction of unconsciousness. The system must be equipped with either windows or video cameras. Captive bolt and electric stunning induce instantaneous unconsciousness. CAS or LAPS requires a period of time to make a bird unconscious. This is why observation of bird behaviour before loss of consciousness is extremely important. The birds

must be visible from entry into the chamber until shortly after loss of posture (LOP). The birds are unconscious when they fall over and can no longer stand (Benson *et al.*, 2012a,b; AVMA, 2016; Mackie *et al.*, 2016). In turkeys, the birds are not able to stand in the transport containers. To substitute for LOP, watch for complete relaxation of their long necks. The turkeys will no longer be able to hold their heads up because they have lost the righting reflex. This is the same as LOP (Meyer, 2015).



Fig. 8.1. An assembled four-deck stacked module that has been placed in the curtain-sided transport trailer. (Photo courtesy of Temple Grandin.)



Fig. 8.2. Two decks from a stacked deck module system exiting the CAS stunning and moving towards the shackle system. (Photo courtesy of Temple Grandin.)

Behaviour Before LOP and Bird Welfare

To maintain acceptable welfare, bird behaviour must be observed before LOP. It is likely that the birds may experience some discomfort before they lose consciousness. Some stress during induction is probably less harmful to bird welfare compared with the obvious severe stress caused by live shackling (Grandin, 2015; Velarde and Raj, 2016). Shackling live chickens is highly stressful (Kannan *et al.*, 1997; Bedanova

et al., 2007). In a poorly managed CAS or LAPS stunner, there is a point where the induction process may become so poor that live shackling may be less stressful. It is the author's opinion that escape behaviour is *never* acceptable. If birds attempt to escape from the container, the gas parameters or air withdrawal specifications must be changed. If large numbers of birds vigorously flap before LOP, this is a definite indicator of severe distress. Other behaviours that may be observed are head shaking and mandibulation (beak opening and closing). The birds exhibiting these behaviours are probably experiencing some discomfort but it is likely that it is less severe compared with the stress of live shackling. Convulsions, flapping and other behaviours after LOP have no effect on bird welfare, but they may have a detrimental effect on meat quality. Many systems have windows that allow direct observation of the birds from the time they first enter the system until loss of posture and unconsciousness. Video cameras can also be used. All CAS and LAPS systems must have either video cameras or windows to view the birds.

CAS and LAPS Systems in Commercial Use

The guidelines from the OIE (2018) state that parameters for CAS stunning are still 'under study'.

Box 8.2. Methods for controlling gas mixtures

- **Horizontal conveyor transport through a series of stations** – In this type of system, a single drawer deck or an entire module with multiple compartments is moved through five to six stations. At each station, the conveyor is stopped and flexible curtains are lowered. In a CO₂-only system, gas levels are slowly raised as an entire module or single drawers advance through a series of stations. CO₂ levels must remain under 40% until the birds lose consciousness. To ensure death, the final station contains 90% CO₂. Horizontal conveyor transport can also be used with other types of gases, such as oxygen and nitrous oxide.
- **Lowered into gas** – In this system either single drawers or modules containing chickens are lowered into a chamber that contains gradually

increasing CO₂. This system is recommended for use with gases that are heavier than air, such as CO₂ or argon. Gravity holds the gas in the chamber. CO₂ levels start at 2–3% and are kept under 40% until the birds have lost posture and become unconscious. To reliably kill the birds, the module or drawer enters a second station containing higher levels of 90% CO₂. Exposure of chickens to greater than 40% CO₂ before loss of consciousness is stressful (Gerritzen *et al.*, 2013).

- **Positive pressure systems** – Entire modules with multiple compartments or entire truck trailers are placed in a chamber and the gas is applied. Many different gases can be accurately applied in this type of system.
- **LAPS system** – Entire modules are moved into a chamber, where air is removed.

Since this book is about the practical application of CAS, this chapter will discuss the best practices for commercial use. The three major technologies that are currently in commercial use are outlined below. They are: (i) gradually increasing CO₂; (ii) biphasic CO₂ and oxygen; and (iii) LAPS (low atmospheric pressure). All good commercial systems are designed to kill the birds prior to discharge from the stunner.

Induction into Gradually Increasing Concentrations of CO₂

Gradual CO₂ induction is a common commercial system. Sudden introduction of chickens into high levels of CO₂ is very aversive to chickens. They will have violent reactions while they are still conscious. Research and the author's own observations indicate that a smooth gradual increase of CO₂ from 0% to 50–55% reduces the bird's reaction prior to LOP (Gerritzen *et al.*, 2013). The mistake that is often made is raising the CO₂ concentration too quickly. Early patents for CO₂ stunning had a two-stage process. This is not recommended. Successful commercial equipment has five more steps to raise the concentration gradually over a period of several minutes (Bright Coop, 2019a,b; Meyn, 2019) (Fig. 8.1). Broiler chickens should show loss of posture (LOP) before the CO₂ levels reach 40%. It is important to keep the CO₂ levels at or below 40% until the chickens

lose consciousness (Velarde and Raj, 2016). The final stage contains 90% CO₂ to kill the birds prior to shackling.

How gradual CO₂ systems work

Gradual CO₂ systems are commercially available in two types of systems. There are large systems where the birds are stunned in modules containing multiple compartments of broiler chickens (Fig. 8.3). The second type is a smaller system where individual drawers containing a group of chickens are removed from the module rack. Each individual drawer is conveyed through the CO₂.

Systems that can handle large modules containing multiple bird compartments use standard industrial freight handling equipment. These systems are similar to the roller platforms that cargo airlines use to move freight modules on to airplanes. The equipment moves the modules to the stunner entrance. As each module moves through the stunning tunnel, it is moved into stations with gradually increasing CO₂. To control CO₂ concentrations, doors or curtains slide down between the stations. After exposure, the doors slide up and the module advances to the next station, where it stops and another set of doors closes. All of the equipment is mounted on the floor. There is no pit.

In older types of gradual CO₂ systems, individual drawers containing chickens are lowered into a pit that contains gradually increasing levels of CO₂

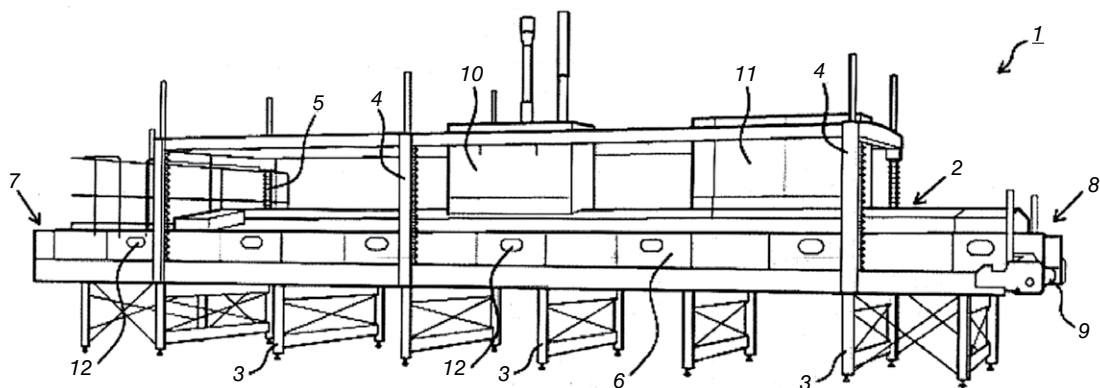


Fig. 8.3. Five-stage CO₂ stunning system for broiler chickens. Modules containing multiple chicken compartments move through a series of chambers with gradually increasing CO₂. (Photo courtesy of Patent Office.)

(Thuolen and Lyngholm, 2013). This type of system can only use gases that are heavier than air. In newer systems, the pit has been eliminated and the chamber is mounted on the floor. The drawers are lowered into increasing levels of CO₂ until 40%. After consciousness is lost, the drawers are transferred to another chamber with 90% CO₂ to ensure death.

Biphasic CO₂ and Oxygen System

Another gas system that is used commercially is the biphasic system. In this system, the chickens are initially exposed to an atmosphere of 40% CO₂, 30% oxygen and 30% nitrogen for 60 s (Abeyesinghe *et al.*, 2007; McKeegan *et al.*, 2007a,b; Coenen *et al.*, 2009). The second stage is the euthanasia phase, which has an atmosphere of 80% CO₂ and air. The biphasic system with added oxygen during the anaesthetic phase has advantages from both a welfare and a carcass quality standpoint (Abeyesinghe *et al.*, 2007; McKeegan *et al.*, 2007a,b; Coenen *et al.*, 2009). In the newest biphasic system, there are five stations with an exposure time of 60 s in each station (Figure 8.4). The first station has 27% CO₂ and 30% oxygen. As the broiler chickens progress through the system, the CO₂ levels are gradually raised. The fifth station has a CO₂ level of 70%. The author observed anaesthesia induction through observation windows and the birds' reactions were mild.



Fig. 8.4. Biphasic – Controlled atmosphere Biphasic stunning system. Marek Stork poultry – Processing patent 10085459b2. (Diagram courtesy of Humane-Aire, Bright Coop.)

The early biphasic systems had small tunnels, because it was easier to maintain the more complex gas mixture in a smaller space. In these early systems, the chickens were removed from the transport container before stunning. This method loses the welfare advantage of systems where the birds remain in the transport containers. They are hung on the shackling line after they are dead but they have to be handled by people or dumped out to put them on a small stunning conveyor. New biphasic systems are excellent from a welfare perspective because they are built with a larger tunnel that can accommodate an entire deck from a stacked deck module system. Maintaining the correct ratio of CO₂ to oxygen must be carefully monitored. McKeegan *et al.* (2007a,b) found that chickens from the CO₂ and oxygen system had fewer broken wings compared

with a hypoxic system of argon and CO₂. From both a meat quality and welfare standpoint, the biphasic oxygen and CO₂ system was superior to 90% argon and air with less than 2% oxygen (Abeyesinghe *et al.*, 2007).

Low Atmospheric Pressure Stunning (LAPS)

In this system, one to three large modules with multiple bird compartments are placed in a pressure vessel chamber. A vacuum pump is used to pull air out of the chamber. LAPS is now approved for use in the European Union for broiler chickens weighing up to 2.9 kg (EFSA, 2017). The conclusion was that LAPS provides a level of welfare at least equivalent to one currently approved method. LAPS, when done correctly, may be equivalent to stunning with inert gases (Martin *et al.*, 2016a,b,c).

One advantage of this system is that it is mechanically simple and has fewer moving parts than staged CO₂ systems (Fig. 8.5a,b). Removal of the air is done in a two-stage process (Martin *et al.*, 2016a). When LAPS is done correctly, there is no escape behaviour and LOP and unconsciousness occurred within an average of 81 s (Mackie *et al.*, 2016). There are two phases in the LAPS cycle: an initial pressure reduction phase followed by a slower rate of decreasing pressure. The specifications for the LAPS in Martin (2016a,b,c) and Holloway and Pritchard (2017) must be followed exactly. Speeding up the process will be highly detrimental to broiler chicken welfare. Compared with gas stunning, more time is required for the chickens to lose consciousness. The process is also sensitive

to environmental changes in barometric pressure and adjustments must be made (Holloway and Pritchard, 2017). The entire cycle is 270–280 s and it must never be speeded up. Monitoring of chicken welfare by observing behaviours before LOP is essential. Research has shown that the birds remain calmer if the chamber is kept dark (Martin *et al.*, 2016b). This would make observation difficult, unless either an infrared camera or a small amount of blue light was used to provide illumination for conventional video.

From a safety standpoint, the metal pressure vessel has to be professionally engineered and built by a certified welder. Improper construction could result in collapse of the chamber. To achieve the air removal rate that has been specified in Mackie *et al.* (2016), a sliding gate valve controlled by a computer is used. One disadvantage of this system has been more broken wings and carcass damage compared with gas stunning systems. This caused one large chicken company to stop using it. Some of the problems at this company were caused by speeding up the air withdrawal time. To comply with EU requirements, LAPS must follow the specifications in Holloway and Pritchard (2017). When LAPS is used correctly, broiler chicken behaviour during induction is similar to inert gases (Mackie *et al.*, 2016). LAPS may not work in turkeys. Informal experiments performed in the industry indicated that turkeys are much more resistant to hypoxia compared with chickens.

Hypoxic Systems Using Inert Gas

The use of an atmosphere that lacks oxygen is favoured by many welfare specialists, because it is

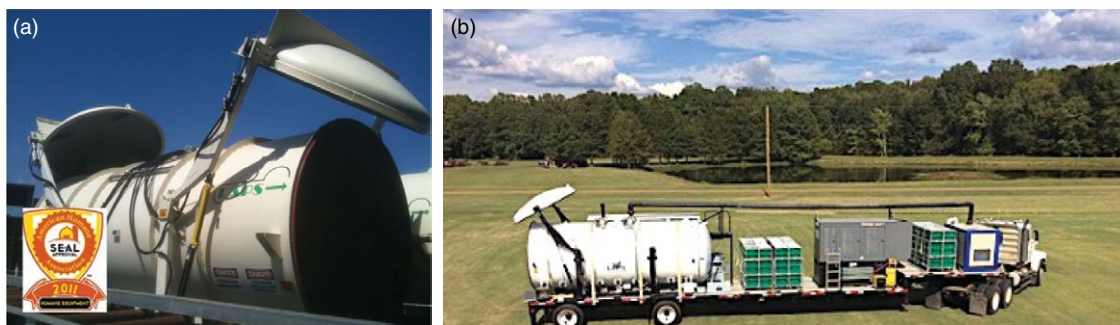


Fig. 8.5. LAPS low atmospheric stunning system for broiler chickens. (a) In a large slaughter plant, multiple modules containing numerous bird compartments can be placed in the chamber. A large abattoir may need two to four chambers. (b) A LAPS system designed for farm depopulation. (From <http://www.lapsinfo.com/press-release>)

not aversive to chickens (Berg and Raj, 2015). These systems use either nitrogen or argon, or these gases are mixed with CO₂. A major problem with these systems is strong convulsions after LOP when the chickens become unconscious. This causes high levels of meat damage (Abeyesinghe *et al.*, 2017). To reduce convulsions, the atmosphere must contain very low levels of oxygen. From an engineering standpoint, this is difficult to achieve in large commercial systems. Nitrogen is especially difficult to use, because it is a major component of air. Gravity will not hold it in a chamber. Attempting to mix nitrogen and CO₂ in equipment designed for CO₂ was a commercial failure due to high wing breakage. To effectively use inert gases in a commercial system would require use of a positive pressure chamber. The main problem with this type of system is that it requires huge quantities of gas. The chamber has to be completely refilled after each batch.

Back-up Systems

Both CAS and LAPS should have back-up systems so that the abattoir can operate if the stunner fails. The most common back-up is a separate electrical stunning line. In CAS or LAPS systems where more than one chamber supplies a single processing line, a back-up system is essential. This prevents the temptation to run the remaining operational chamber at an increased speed, which would be highly detrimental to bird welfare.

Other Types of Gases

It has been suggested to use carbon monoxide to euthanize poultry or other animals. This gas is too dangerous and can quickly kill people. From a safety standpoint, it should never be used in a commercial abattoir. A patent has been filed for a novel mixture of oxygen, CO₂ and nitrous oxide (Larsen *et al.*, 2016). This gas mixture will require further research before it is used commercially.

Whole Truck CAS Stunning System

Several turkey companies in the USA have systems where a truck loaded with turkey modules enters a building that looks like a truck wash (Lang *et al.*, 2008). Stainless steel panels automatically clamp on the sides of the trailer and pass gradually increasing levels of CO₂ into compartments that

hold the turkeys. The trailer has to be modified with partitions to seal off each section. The author has observed this system and it does work. If it is cycled too rapidly and speeded up, the turkeys have a poor induction. The major problem with whole-trailer stunning is that it wastes vast quantities of CO₂ unless it is equipped with expensive devices to recapture the exhausted CO₂.

Removal of Birds Dead on Arrival (DOA)

From a food safety perspective, birds that arrive at the abattoir dead on arrival must not be processed for food. Practical experience has shown that birds that arrive dead can be easily identified and removed by shacklers. These birds are usually stiff or cold. Ouckama *et al.* (2018) reported that they could detect DOAs within 5 min post-mortem. They assessed hock stiffness, which is a sign that rigor mortis has started.

Choosing a System

To make a commercially viable system that protects bird welfare and has low levels of meat damage, gradually increasing levels of CO₂ or biphasic usually is the best option. All CAS and LAPS systems must be constantly monitored to maintain a smooth induction. Escape attempts should be abolished and wing flapping should occur in 5% or less of the birds. Outcome variables should be used to evaluate future innovations. See Chapters 11 and 13 for further information on assessing behaviour before loss of posture.

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9

Stunning of Pigs and Sheep with Electricity and CO₂

TEMPLE GRANDIN*

Department of Animal Science, Colorado State University, USA

Summary

Properly applied electric stunning will instantaneously make an animal unconscious by inducing a grand mal epileptic seizure. The three types of electrical stunning are: (i) head-only reversible; (ii) head-to-back cardiac arrest; and (iii) sequential head-to-back or body cardiac arrest. The electrodes must be placed so that the electric current flows through the brain. Electrical stunning of dehydrated animals may be less effective. When CO₂ is used, induction of unconsciousness is not instantaneous. There are welfare concerns about the aversiveness of CO₂ inhalation. Some discomfort during induction may be a reasonable tradeoff because the group handling system eliminates electric prods. Behaviour before loss of posture (LOP) should be observed. If the animal attempts to escape, the stress during induction is excessive and not acceptable.

Learning Objectives

- How electrical stunning induces unconsciousness.
- Correct electrode positions for electrical stunning.
- What are the animal welfare concerns with CO₂ stunning.
- How to correct and fix operational problems with stunning in a commercial abattoir.

Introduction

For pigs, the commonly used methods in commercial abattoirs are either electrical or CO₂ stunning. For sheep or lambs, electrical stunning or captive bolt are common methods. In this chapter, the reader will learn the proper use of these methods. Effective stunning that reliably renders an animal

unconscious requires the right equipment and also management who will pay close attention to both maintenance and details of the procedures.

Principles of Electrical Stunning for Pigs, Sheep or Goats

To induce instantaneous unconsciousness, a sufficient electric current must pass through the animal's brain to induce a grand mal epileptic seizure (Croft, 1952; Warrington, 1974; Lambooy and Spanjaard, 1982; Anil and McKinstry, 1998; AVMA, 2016; HSA, 2018). When head-only electrical stunning is done correctly, there will be a rigid tonic phase followed by a clonic kicking phase. During the tonic phase, the animal will be rigid. When the kicking phase stops, the animal will recover and becomes conscious. Electrical stunning methods are outlined in [Box 9.1](#).

Tips on Electrical Stunner Positioning

An electrical stunning tong or other apparatus must never be applied to a sensitive part of the animal such as eyes, ears or rectum. Correct placement is essential to reliably make the animal instantly unconscious (Anil and MacKinstry, 1998). Acceptable positions for stunning are as follows.

- Simultaneous application to the forehead and back (cardiac arrest) of pigs and sheep (Gregory and Wotton, 1984; Wotton and Gregory, 1986). In a welfare audit, assess position of the head electrode. On sheep, the electrodes may also be placed on the top of the head and the chest (Mason *et al.*, 2018). This method will induce cardiac arrest. Due to their large size, do not use simultaneous head-to-body application for cattle.

* Email: cheryl.miller@colostate.edu

Box 9.1. Types of electrical stunning

There are three basic methods for applying electrical stunning.

- **Reversible head-only** – Fig. 9.1 shows head-only electrical stunning. The tongs are used to pass an electric current through the brain. This is a fully reversible stun. To prevent recovery of consciousness, the animal must be bled within 10–15 s (Blackmore and Newhook, 1981; Lambooi, 1982; Grandin, 1986). This method will be discussed in detail in the chapter on religious slaughter (Chapter 11), because many religious authorities will accept a fully reversible stun where the animal can fully recover. Maintaining the full 1 amp is essential for effective head-only stunning of commercial pigs (Viegh *et al.*, 2017).
- **Simultaneous head-to-body cardiac arrest** – Figs 9.2 and 9.3 show simultaneous head-to-back cardiac arrest stunning. When this method is used, the electric current is simultaneously passed through the animal's brain and heart. When correctly applied, it will simultaneously induce instantaneous unconsciousness and kill the animal by cardiac arrest. From an animal welfare standpoint, this is the preferred method (Gregory and Wotton, 1984; Wotton and Gregory, 1986). If bleeding is delayed, the animal will not recover. The head electrode must never be placed on the neck, because the current would fail to pass through the brain. Cardiac arrest would occur but the animal would still be conscious. In pigs, the head electrode can be placed in the hollow behind the ear (Fig. 9.2). In sheep, Velarde *et al.* (2000) found that the more

forward position was more effective. Sheep have wool and it is an insulator. Stunning was more likely to be effective on sheep with short wool and when the application area was wetted. This is the reason why commercial head-to-back electrical stunners for sheep have a system for passing water through the electrodes to wet the skin surface.

- **Sequential head-to-body cardiac arrest stunning** – This method is especially useful in small abattoirs where the animals are electrically stunned with tongs while standing on the floor (Fig. 9.1). A head-to-back stunner (Figs 9.2 and 9.3) works poorly in this situation, because the animal will fall away from the head-to-back tong (wand). There is no restrainer conveyer or other restraint to hold the animal up. In the sequential method, the tong is first used to stun across the head to induce instantaneous unconsciousness. Immediately after removal from the head, the tong is re-applied right behind the elbow to induce cardiac arrest (Vogel *et al.*, 2010) (Fig. 9.4). The electrodes must always be applied to the head first to induce unconsciousness. Before this method was developed, small abattoirs where pigs or sheep were head-only stunned on the floor often had problems with animals returning to consciousness. This occurred because recovery started before the sheep or pigs could be shackled, hoisted and bled. The sequential method is also used for cardiac arrest stunning of cattle (Wotton *et al.*, 2000; Weaver and Wotton, 2008).

- Simultaneous application to the hollow behind the ear and body (cardiac arrest) of pigs. Assess position of head electrode only.
- Between the eye and ear on both sides of the head with a tong-type stunner for pigs and sheep (reversible head-only).
- Cattle nose-to-neck in a stanchion (reversible head-only for religious slaughter) (Wotton *et al.*, 2000).
- Top of head and under the jaw with a tong-type stunning (reversible head-only).
- Two-stage cardiac arrest stun for cattle, nose-to-neck followed by neck-to-brisket electrode (Wotton *et al.*, 2000; Weaver and Wotton, 2008).
- Two-stage cardiac arrest stun for pigs, sheep or goats. Application across the head followed by a

second application to the chest (Vogel *et al.*, 2010). The head stun must be applied first. This method is especially recommended for small abattoirs that stun groups of animals on the floor.

How Electricity Works

Electricity and water share some characteristics. Volts are analogous to water pressure and amperage is analogous to the amount (volume) of water. There has to be sufficient voltage to drive the required amperage through the animal's brain. Modern electrical stunning units will automatically deliver the required amperage. The voltage will automatically vary. On older stunning units, the voltage is set and the amperage will vary depending on the animal's



Fig. 9.1. Head-only electrical stunning with the tongs in the correct position to pass the current through the brain. This is essential to induce instant unconsciousness by causing a grand mal epileptic seizure. (From T. Grandin, 2010.)



Fig. 9.3. Head-to-back cardiac arrest electrical stunner. The head electrode must never be placed on the neck. It must either be in the hollow behind the ears or on the forehead. Placing the body electrode on the side of the body helps reduce blood spotting in the meat. (From T. Grandin, 2010.)



Fig. 9.2. Head-to-back cardiac arrest electrical stunning. It simultaneously induces unconsciousness and cardiac arrest. (From T. Grandin, 2010.)



Fig. 9.4. Second step of a sequential cardiac arrest stunning procedure for pigs. The tong is first applied to the head to induce unconsciousness and then immediately applied to the chest to stop the heart. This chest position helps reduce meat damage. (Photo courtesy of Erika Voogd.)

resistance. Dehydrated animals or failure to wet the electrode application site can cause electrical stunning failures in all species of livestock (Grandin, 2001) and poultry. Dehydrated animals that have been off water for too long are poor conductors of electricity. If animals arrive at the slaughter plant in a severely dehydrated condition, a few hours in the lairage with drinking water may not be sufficient to recover. The author has observed that dehydration is a common cause of electrical stunning failures in cattle, sheep and pigs.

Minimum Amperage Requirements for Different Types of Livestock

Table 9.1 shows the minimum amperage requirements for different types of livestock. This table is

Table 9.1. Minimum current levels for head-only electrical stunning at 50–60 cycles (from AVMA, 2016; OIE, 2018).

Species	Current level
Cattle	1.5 amps
Calves (bovines of less than 6 months of age)	1.0 amps
Pigs	1.25 amps
Sheep and goats	1.0 amps
Lambs	0.7 amps ^a
Ostriches	0.4 amps

^aBoth EFSA (2015) and HSA (2016) require 1 amp for lamb

in the latest version of the OIE 2018 slaughter guidelines.

The current levels should be maintained for 1 s after the initiation of the stun. To ensure reliable induction of unconsciousness, the tong should be applied for 2 or 3 s. When head-to-back stunning is used, a higher amperage may be required, because the current has to travel a greater distance through the body. When the original research was done to determine the 1.25 amp setting, lighter 100 kg (220 lb) pigs were used. In North America, larger 130 kg (275 lb) pigs are common. These larger animals will require higher amperage settings (NAML, 2017).

Monitoring of Electrical Stunning

In many abattoirs, voltage and amperage meters are monitored to ensure that the stunner is delivering the required amperage (Velarde and Raj, 2016). Monitoring of meters is also done to comply with regulatory requirements. At regular intervals throughout the day, the readings are recorded. Computerized stunners are available that will automatically record the amperage and voltage of every stun.

Reading meters is not sufficient to ensure that all the animals are made instantly unconscious. Animal welfare officers, inspectors and auditors need to know how to determine if the stunner is causing a grand mal seizure. When head-only stunning is done for 2 or 3 s, it is easy to observe a distinct rigid (tonic) and kicking (clonic) phase. The presence of the tonic and clonic spasm is evaluated after the electrical stunner tong is removed from the head. When testing for tonic and clonic spasms, the tong should be held on for 1–3 s. Holding the tong on too long, for over 5 s, may depolarize the spine and mask the seizure.

Electrical stunner effectiveness may also be difficult to evaluate if a plant uses an immobilizing current to hold the carcass still after stunning. This is used in some beef abattoirs. To observe the clonic and tonic spasm, the immobilizer current must be turned off. If the stunner is not capable of inducing an epileptic seizure, it should not be used. The use of low currents or very high frequencies will result in paralysing a sensible animal. Electrical immobilization must never be used as a substitute for effective electrical stunning that induces a grand mal seizure (OIE, 2018). It is highly aversive

and detrimental to welfare (Lambooij and VanVorst, 1985; Grandin *et al.*, 1986; Pascoe, 1986; Rushen, 1986).

If a head-only stunner is left on for 10–20 s, the seizure may be completely masked because the spinal column becomes depolarized. Head-to-back stunning and sequential electrical stunning can also mask the full tonic and clonic phases of the seizure. When it is applied for 2–3 s, there should still be slight signs of a tonic and a clonic phase. A sign that electrical stunning is not working is when the carcass is too still after a stun of 2–3 s.

Electrical Cycles (Frequency) on Stunning Effectiveness

Regular electric mains (house) current provided from a commercial power station operates at 50 cycles in Europe, Asia, Middle East, Russia and Africa. The electricity frequency is 60 cycles in Canada, USA, Mexico and Central America. South America is mostly 50 cycles with a few exceptions, such as Brazil, which is 60 cycles.

Low frequency 50- or 60-cycle electricity is more effective for stunning than higher frequencies. **Figure 9.5** shows the difference between standard 50 or 60 Hz waveform and a 200 Hz waveform. The higher frequency has more cycles that the current makes per second.

Research clearly shows that 50 or 60 Hz provides superior stunning results compared with higher

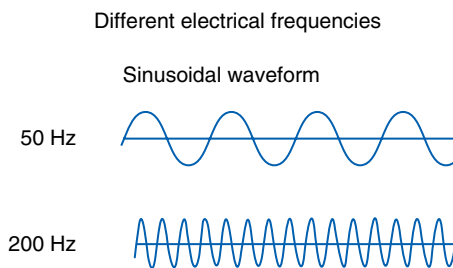


Fig. 9.5. Tracing of electrical sinusoidal waveforms to show the difference between standard 50 Hz and 200 Hz electrical waveforms. Lower frequencies make electrical stunning more effective but they are more likely to cause meat damage in livestock and poultry. Research has been done to determine the best frequencies that reduce meat damage but still protect animal welfare with effective stunning.

frequencies. Low frequencies of 50–60 Hz have a greater ability to penetrate tissues. One of the reasons why people want to use higher frequencies is to reduce blood spotting and other damage to the meat. Higher frequencies can be used, but higher voltage will be required. For example, OIE (2018) guidelines for poultry require double the standard 100 mA recommendations for frequencies over 400 Hz. Another disadvantage of higher frequencies is that the time that the livestock or poultry remain unconscious is shorter.

Higher frequencies will reduce the length of time that pigs will remain insensible (Anil and McKinstry, 1992). Very high frequencies of 2000–3000 Hz fail to induce insensibility and should not be used (Croft, 1952; Warrington, 1974; Van der Wal, 1978). Frequencies of 1592 Hz sine wave or 1642 Hz square wave will induce insensibility in small pigs (Anil and McKinstry, 1992). Some effective commercial systems apply an 800 Hz current to the head, followed by a 50 Hz current applied to the body. This combination is effective (Lambooij *et al.*, 1997; Berghaus and Troeger, 1998; Wenzlawowicz *et al.*, 1999). High frequencies applied to induce cardiac arrest must never be used. Practical experience with a European tong-type stunner showed that 400 Hz applied to the chest failed to induce cardiac arrest in pigs.

Correcting Electrical Stunning Problems

Box 9.2 describes the reasons for problems that may be encountered during electrical stunning.

Carbon Dioxide (CO₂) Stunning of Pigs

CO₂ stunning of pigs is the major method that is used in large slaughter plants in both Europe and the USA. Electrical stunning induces instantaneous unconsciousness. When CO₂ stunning is used, the pigs have to breathe CO₂ gas for 20–30 s before they become unconscious. Smaller plants often use electrical stunning because the equipment is less expensive. One reason CO₂ has become the preferred method is that it reduces meat damage such as petechial haemorrhage and blood spots in the pork (Gregory, 2005). US abattoir managers have been motivated to switch to CO₂ to reduce broken backs in heavyweight 125 kg (275 kg) market pigs caused by electrical stunning. Broken backs are not a welfare concern, because the pig is unconscious, but they can cause serious meat damage. This is the commercial reality, even though there are animal welfare concerns about the aversiveness of CO₂ (Raj and Gregory, 1996; Becerill-Herrera *et al.*, 2009; Dalmau *et al.*, 2010).

One big advantage of the large CO₂ machines is that the pigs are handled in groups and the use of

Box 9.2. Electrical stunning problems

- **Pigs squeal or cattle bellow when the stunner is applied** – This occurs because the tong or other device was not pressed firmly against the animal before the current was turned on.
- **Poor electrical contact** – Wet either the animals or the electrodes. Never use sharp pin electrodes. Enlarging the surface area of electrode may improve electrical contact.
- **Sliding or bouncing the tong during application** – This can cause both meat quality problems and failure to induce instantaneous unconsciousness. If the wand bounces or slides, it causes the animal's muscles to contract more than once.
- **Dirty contacts, worn-out power receptacle or damaged wires** – May cause a drop in the current.
- **Meters are broken** – A faulty meter may give wrong readings. The electrical box must be kept dry. It must never be sprayed with water. Many

people get too reliant on the meters. Looking at the reaction of the animal is more important to make sure that a seizure is induced.

- **Dirty electrodes** – Electrodes must be kept clean to maximize current flow.
- **Electrode contact area too small** – In some systems, enlarging the contact area of the electrode may improve stunning.
- **DEHYDRATED ANIMALS** – This is in capital letters because electric stunning works poorly on dehydrated animals that have been off water for too long. If an electrical stunner suddenly starts failing, check where the animals came from. The author has observed problems with dehydrated animals in cattle, sows and lambs. This problem must be corrected by the producer or transporter. A drink of water in the lairage 2 h before stunning will usually not solve this problem.

electric prods during handling can be completely eliminated. Cortisol levels were significantly lower in pigs handled in groups (Jongman *et al.*, 2017). Figure 9.6 shows a group of pigs ready to be moved into the chamber. Handling is greatly improved compared with moving several hundred pigs per hour through a single file race for electric stunning. When high numbers of pigs are moved through a single file race, electric prods will usually be needed to move about 15% of the pigs. Another advantage is that CO₂ stunning with long dwell times in the gas can almost eliminate problems with pigs regaining consciousness. In the USA, the Department of Agriculture's Food Safety and Inspection Service (FSIS) regulatory authority can shut an abattoir down if animals regain consciousness after stunning. This has motivated many abattoir companies to switch from electrical to CO₂ stunning. Pressure from animal activist groups has resulted in increased enforcement of US Humane Slaughter regulations. The author has observed that this has resulted in increased use of CO₂ because it makes it easier to comply with US regulations.

Welfare Controversy

The World Organisation for Animal Health (OIE) recommends that the CO₂ gas concentration must be 80% or 90%. Many commercial units in the USA are run at higher concentrations. The standard best practice is to quickly lower the pigs into 90% or greater levels of CO₂ (Becerril-Herrera *et al.*, 2009). One indicator of the continuing controversy about CO₂ stunning is that the OIE



Fig. 9.6. A group of pigs getting ready to enter the CO₂ stunner. After the gate on the left side opens, the powered pusher gate on the right will move the pigs into the gondola. Group handling greatly reduces pre-stunning stress. (Photo courtesy of Temple Grandin.)

(2018) guidelines are still under study and the Humane Slaughter Association (HSA, 2018) has no guidance for CO₂ stunning of pigs. HSA has extensive guidance for electrical stunning, captive bolt stunning and gas (controlled atmosphere) stunning of poultry. Guidance from the European Food Safety Authority (EFSA) is also less detailed (EFSA, 2018) for controlled atmosphere stunning (CAS). EFSA has extensive guidance documents for other stunning methods. Both EFSA (2004, 2015) and the HSA are encouraging the development of new or modified gas stunning methods (EFSA, 2017, 2018).

One of the problems with alternatives to CO₂ has been pork quality (Llonch *et al.*, 2012a). CO₂ stunning had superior pork quality compared with head-to-brisket electrical stunning (Channon *et al.*, 2002). Another problem is that only gases that are heavier than air will work in the existing CO₂ machines. This limits the gases to CO₂ and argon. Other gases, such as nitrogen, will not stay in the chamber, because it is an open system dependent on gravity to confine the gas in a deep pit. The use of these gases may require the use of a different type of chamber. The use of other gases such as CO₂ and nitrogen, or CO₂ and argon, will reduce aversiveness (Raj and Gregory, 1996; Dalmau *et al.*, 2010; Llonch *et al.*, 2012b).

Assessing the Reaction of Pigs to CO₂ or Other Gases

Both captive bolt and electrical stunning induce instantaneous unconsciousness. When CO₂ or other controlled atmosphere methods are used, 20 or more seconds may be required before the pigs have loss of posture (LOP) (Velarde *et al.*, 2007). From an animal welfare standpoint, the most important part of the process is the induction phase before the pigs fall over and lose the ability to stand. The pigs will be unconscious either at the time of LOP or 2–10 s after LOP (Verhoeven *et al.*, 2016b). Verhoeven *et al.* (2016b) defined loss of posture as when the pig is in a recumbent position and it has totally lost control of posture. Convulsions, kicking and squealing that occur after LOP are less of a welfare concern.

Even though there is a possibility of some awareness after LOP, this measure is still useful for preventing the worst problems. Commercial abattoirs need assessment tools they can easily use. It is also possible that the pigs were in the transition zone between full

consciousness and brain death in the Verhoeven *et al.* (2016a,b) study (see Chapter 14). Verhoeven *et al.* (2015) stated: ‘The exact moment when unconsciousness sets in, based on EEG, is difficult to determine as change is often gradual.’ Benson *et al.* (2012) determined that chickens became unconscious when they fell over and lost posture. Why have Verhoeven *et al.* (2016b) reported different results in pigs? This may be due to differences in the methods used to evaluate the EEG. Benson *et al.* (2012) used medical software that assessed the alpha–delta wave ratio and Verhoeven *et al.* (2016b) used a more subjective method of the visual appraisal of the EEG. When LOP occurs, it is the first step in becoming unconscious (Terlouw *et al.*, 2016a,b).

Another issue that has to be examined when assessing reactions to CO₂ or other controlled atmosphere stunning methods is the condition of the lungs. In commercial market-weight pigs, observations by people working in the industry indicate that 7–8% may have severe lung lesions. Lung lesions may increase the time required to lose consciousness. This is an area that will require more research.

Video Cameras Required to Evaluate Pig Reactions in Large CO₂ Machines

Assessment of the pigs’ reactions in large commercial CO₂ machines will require the use of video cameras installed in the pit. In a typical large machine, the gondolas travel through the CO₂ on a continuous conveyor, similar to a skinny Ferris wheel. Viewing the pigs when they reach the bottom of the deep pit is extremely difficult, because the next gondola blocks the view. In small dip-lift machines that have a single gondola, which goes up and down like an elevator, it is easy to see the pigs through the entire process. Poultry systems are easier to evaluate through either windows or video cameras, because most systems are in cabinets that are mounted on top of the abattoir floor.

Researchers have found that there is an excitation phase that occurs before the loss of consciousness (Hoenderken, 1978, 1983; Rodrigues *et al.*, 2008). Loss of posture or escape movements could not be assessed by Rodrigues *et al.* (2008), because the pigs were held in a net sling. It is the author’s opinion that some discomfort, such as head shaking or gasping, may be an acceptable tradeoff to achieve low-stress handling with no electric prods.

It is also the author’s opinion that when escape attempts occur, the pig’s welfare is not acceptable. An escape attempt is scored if a pig attempts escape from the gondola or other container. After the pigs were lowered into the gas, Verhoeven *et al.* (2016b) observed signs of pig aversion to CO₂ but 0% attempted to escape.

Genetic Differences in Pig Reaction to CO₂

A possible best way to improve animal welfare during induction of CO₂ anaesthesia is genetic selection. Dodman (1977) reported that the reaction of pigs to CO₂ was high variable. Forslid (1987) used EEG to determine that, in purebred Yorkshire (Large White) pigs, the excitation phase occurred after loss of consciousness. Unfortunately, he never tested any other breeds of pig.

Grandin (1988) observed pigs in small CO₂ machines where their reactions could be viewed. These observations were conducted before the large breeding companies had introduced large numbers of hybrid pigs. It would have been a genetically diverse population. The pigs were a mixture of breeds and colours. Some pigs struggled violently and others had a calm induction. The pigs were definitely having a reaction to the gas. The initial movement of the gondola had no effect on the pigs’ behaviour. Grandin (1988) concluded that genetic factors may have had an effect on the pigs’ reactions. Pigs that were white and had Yorkshire breed characteristics had a calmer induction than pigs that were black with a white belt, which is characteristic of the Hampshire breed. The next study, by Troeger and Wolsterdorf (1991), indicated that pigs with the halothane stress gene had a worse reaction during induction. Velarde *et al.* (2007) were the first researchers to test pigs with a known halothane genotype. They evaluated Duroc × Yorkshire pigs, which were homozygous halothane stress gene free, and Piétrain × Large White pigs that were carriers (heterozygotes). A concentration of 70–90% CO₂ was used, which is low compared with properly operated commercial units. For the carrier pigs, 67% attempted to escape from the gondola; for the pigs that were completely free of the stress gene, 46% of the animals attempted to escape (Velarde *et al.*, 2007). In Yorkshire × Landrace pigs, being shocked by an electric prod was more aversive than CO₂ (Jongman *et al.*, 2000).

The author's own observations of pigs being introduced into CO₂ have ranged from a very peaceful induction in Danish homozygous halothane stress gene free pigs to the most vigorous escape attempts in other pig breeds. The pigs that had the worse reactions likely carried the stress gene and they were handled poorly with numerous electric prods. The Danish observations were made in a special research machine where a group of pigs entered the CO₂ very quietly. There was sufficient space in the gondola for the pigs to walk around. A few pigs sniffed the CO₂ and backed up. After LOP, the violent reaction occurred. The chamber had a concentration of 90% CO₂. Patricia Barton, a researcher at the Danish Meat Research Institute, always maintained that it is really important to have a calm pig entering the CO₂ gondola.

Observations in Large Butina Machine with Video

More recent observations of US commercial hybrid pigs by the author indicated that 20–30% had a calm induction before loss of posture. Eleven per cent had a definite escape reaction. The pigs were stunned with 90% CO₂ in a Butina machine with group handling. Determining the exact numbers of calm inductions was difficult, due to the gondola being loaded to the standard commercial capacity. All the pigs were quietly moved into the gondola and electric prods were not used on any of the pigs.

The pigs were all commercially available hybrids with unknown genetics. All the animals were white with grey areas on their hindquarters or shoulders. They had partially floppy ears that may indicate both Yorkshire and Landrace genetics. The grey areas may indicate Hampshire genetics. The coloration of the pigs indicates that it is likely they were free of Duroc or Piétrain genetics. They had no black spots or brown coloration.

Studies done in Australian abattoirs with CO₂ indicated that there was a large variation in escape/crawl reactions between different abattoirs and different farms (Jongman, 2017). Escape/crawl reactions varied from 6% to 46% of the pigs.

Evaluation of Future Controlled Atmosphere Stunning

EFSA (2018) adopted a document on guidelines for evaluating new systems. It has an excellent table (Table 9.2) for evaluating new systems. This

table contains both behavioural and physiological measures. The table's behavioural measures should be used *before* loss of posture. Terlouw *et al.* (2016a,b) and Chapter 13 provide additional guidance.

When physiological measures are used, one must remember that increases in epinephrine that occur after the animal becomes unconscious have no effect on animal welfare. Captive bolt and electrical stunning both increase physiological measures of stress (Van der Wal, 1978). Since induction of unconsciousness is instantaneous, the increase in catecholamines would have no effect on the welfare of a properly stunned animal.

Operation Problems in the Slaughter Plant

Operation problems with CO₂ and other CAS methods that can compromise animal welfare are outlined in Box 9.3.

Management Decisions about Electrical or Controlled Atmosphere Stunning

CAS systems are expensive to buy and maintain but require less oversight by management during day-to-day operations compared with electrical stunning. When CAS is working properly, problems with pigs or poultry regaining consciousness can almost be eliminated. Electrical stunning is economical to buy and much cheaper to operate than CAS. To prevent pigs from regaining consciousness, electrical stunning requires a lot more attention to details of procedure such as electrode (tong) positioning and wetting the animals. Another disadvantage of electrical stunning is that it is more difficult to train people how to correctly evaluate unconsciousness. Stunning pigs in a large CO₂ machine with a long exposure time results in floppy pigs with all reflexes eliminated (Fig. 9.7). The floppy carcasses are both safer and easier to handle for the person who does the bleeding.

Conclusions

Both electrical stunning and CO₂ stunning require calm, low-stress handling. Agitated excited animals are more difficult to stun. There are tradeoffs. Electrical stunning, when properly applied, induces instantaneous unconsciousness, but low-stress

Table 9.2. EFSA (2018) overview of categories of animal-based measures associated with pain, distress and suffering during the induction of unconsciousness with CAS stunning. Assess behavioural measure *before* loss of posture (LOP). (Table adapted from EFSA, 2018, 'Guidance on the assessment criteria for application for new or modified stunning methods regarding animal protection at the time of killing'.)

Category of animal behaviour measures (ABMs)	ABMs	Examples	References
Behavioural measures	Vocalizations	Number and duration, intensity, spectral components	EFSA, 2005; Le Neindre <i>et al.</i> , 2009; Atkinson <i>et al.</i> , 2012; Landa, 2012; Llonch <i>et al.</i> , 2012a, 2012b, 2013
	Postures and movements	Kicking, tail flicking, avoidance	Jongman <i>et al.</i> , 2000; EFSA, 2005; McKeegan <i>et al.</i> , 2006; Gerritzen <i>et al.</i> , 2007; Velarde <i>et al.</i> , 2007; Kirkden <i>et al.</i> , 2008; Svendsen <i>et al.</i> , 2008; Dalmau <i>et al.</i> , 2010; Atkinson <i>et al.</i> , 2012; Landa, 2012; Llonch <i>et al.</i> , 2012a, 2012b, 2013; Verhoeven <i>et al.</i> , 2015a,b
	General behaviour	Agitation, freezing, retreat attempts, escape attempts	EFSA, 2005; Velarde <i>et al.</i> , 2007; Dalmau <i>et al.</i> , 2010; Landa, 2012
Physiological measures	Hormone concentrations	HPA axis: corticosteroids, ACTH; sympathetic system; adrenaline, noradrenaline	Mellor <i>et al.</i> , 2000; EFSA, 2005; LeNeindre <i>et al.</i> , 2009; Coetzee <i>et al.</i> , 2010; Landa, 2012
	Blood metabolites	Glucose, lactate, LDH	EFSA, 2005; Vogel <i>et al.</i> , 2010; Landa, 2012; Mota-Rojas <i>et al.</i> , 2012
	Autonomic responses	Heart rate and heart rate variability, blood pressure, respiratory rate, body temperature	Martoft <i>et al.</i> , 2001; EFSA, 2005; Von Borell <i>et al.</i> , 2007; Gerritzen <i>et al.</i> , 2007; Rodriguez <i>et al.</i> , 2008; Svendsen <i>et al.</i> , 2008; Le Neindre <i>et al.</i> , 2009; Dalmau <i>et al.</i> , 2010; McKeegan <i>et al.</i> , 2011; Atkinson <i>et al.</i> , 2012; Landa, 2012; Llonch <i>et al.</i> , 2012a, 2012b, 2013
Neurological measures	Brain activity	EEG, ECoG	Gibson <i>et al.</i> , 2009a,b

Box 9.3. Operation problems with CAS methods that can compromise animal welfare

- Undersized machine** – An overloaded, undersized machine is one of the worst problems with all types of gas stunning (Grandin, 2015). As a plant increases production, the machine may become overloaded. Plant managers who are purchasing a gas stunning machine should purchase a large enough machine to handle future increases in production. An overloaded machine has to be replaced. Specific signs of an overloaded machine are: (i) animals are not rendered insensible, because the exposure time has been decreased by speeding up the conveyor; and (ii) gondolas or containers are overloaded and pigs or birds do not have enough room to stand or lie down without being on top of each other. Pigs should never be forced to jump on top of other pigs when a gondola is being loaded.
- Problems with maintaining the correct gas concentration** – Another problem that can occur is that gas is not evenly distributed in the chamber. This may be due to either a design fault in the chamber, or the ventilation system in the abattoir may be sucking the gas out of the chamber. Correcting this problem may require the expertise of an engineering professional skilled in ventilation systems. In open gas stunning systems that depend on gravity to hold either CO₂ or argon in the chamber, several problems may occur. Some of the problems are caused by wind blowing around the plant building, changes in the number of ventilation fans turned on in the abattoir, or opening and closing doors near the chamber. These factors can cause 'stack pressure' that may cause the gas to be sucked out (Grandin, 2015). Stack pressure is a common

Continued

Box 9.3. Continued.

cause of a sudden appearance of conscious animals emerging from a chamber that has been operating effectively. This may occur when a certain specific sequence of either opening doors or turning on ventilator fans occurs. Doors that slam hard by themselves are moved by differences in air pressure between two rooms or between a room and the outdoors. Differences in air pressure in

rooms near the gas stunning equipment may cause the stunner to fail. Stack pressure problems will have no effect on positive pressure (closed) systems where the gas is introduced into the chamber with a ventilation system. Low air pressure systems that are discussed in the poultry chapter (Chapter 8) are also not affected by air pressure differences within a building.



Fig. 9.7. Pigs discharged from a CO₂ machine are limp and floppy. The large CO₂ machines used in big commercial abattoirs have a dwell time that is sufficiently long to kill the pigs. This reduces many problems with pigs regaining consciousness. (Photo courtesy of Temple Grandin.)

handling of the animals before stunning is more difficult. When CO₂ or other CAS is used, low-stress handling before stunning is much easier and electric prods can be eliminated. All types of CO₂ or other controlled atmosphere stunning should be monitored with video cameras. Behaviour before loss of posture should be evaluated.

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10 Basics of Captive Bolt Stunning of Cattle and Other Animals

FAITH BAIER^{1*} AND DENNIS WILLSON²

¹*Department of Dairy Science, University of Wisconsin, Madison, USA;*

²*Department of Animal Science, Colorado State University, USA*

Summary

Captive bolt guns and firearms are used to humanely induce unconsciousness in animals being slaughtered, euthanized or depopulated. A secondary method such as pithing, exsanguination or injectable agents should be used immediately after a captive bolt stun to ensure death occurs. Using a firearm does not require a secondary method to ensure death if the proper firearm and ammunition are chosen for the species being killed. The most important considerations in using captive bolt guns and firearms are regular cleanings, maintenance and safety. A captive bolt gun is safer than a firearm, because a firearm produces a free projectile. A review of the data shows that stunner placement at very small abattoirs accounts for the majority of humane handling enforcement actions in 2017 by the United States Department of Agriculture's Food Safety and Inspection Service (USDA FSIS). Low incidence of equipment failure indicates that abattoir managers have greatly improved gun maintenance.

Learning Objectives

- Learn about penetrating and non-penetrating captive bolt.
- The importance of good maintenance of stunners.
- Correct stunner placement for different types of animals.
- How to prevent stunning problems.
- Best practices for stunning.

Types of Captive Bolt Guns

Captive bolt guns are commonly used to stun animals, rendering them instantly insensible with no pain before exsanguination and dressing. A captive bolt gun applies physical trauma to the brain to produce an unconscious state in the animal. When a captive bolt gun is fired, a metal bolt or rod is propelled forward and out of the gun towards the animal's head. The bolt can be powered pneumatically or with a blank, powder-filled cartridge. There are two main types of captive bolt guns: large, pneumatically powered guns; and handheld guns powered by a cartridge. Captive bolt guns produce a penetrating or non-penetrating blow.

Penetrating captive bolt guns

Penetrating captive bolt guns have a bolt or rod that is propelled from the gun and enters the animal's head, specifically targeting the brain. The bolt then retracts into the shaft of the gun. Penetrating captive bolts cause irreversible physical damage to the animal's brain, making revival highly unlikely. Penetrating captive bolt guns are commonly used to stun cattle (AVMA, 2016). The humane slaughter of horses, swine and other food animals is discussed in the section, 'Recommendations of other species'.

Pneumatic captive bolt guns

Pneumatic captive bolt guns are powered by compressed air, which provides the energy to propel the bolt forward and out of the gun. Guns from different

* Email: fbaier@wisc.edu

manufacturers may have different air requirements for pressure and volume of air. Pneumatic captive bolt guns are commonly used at large cattle abattoirs. The gun is hung over the stun box as shown in Fig. 10.1. A pneumatic stunning system consists of three main parts: the gun; the spring-loaded cable balancer; and the air supply. It is critical to maintain all three parts for the pneumatic captive bolt gun to stun animals effectively. The balancer is mounted above the gun and compensates for the heaviness of the gun, providing the stun operator with a comfortable weight and ample range of gun movement. The air supply that powers the gun is a very important part and it must be regularly maintained. The main maintenance items are filling the lubricator, draining water from the tank and changing the air filter. For example, a Jarvis pneumatic stunner is operated with 190 pounds per square inch (psi) of air pressure (1310 kPa). The air pressure in an operating pneumatic gun should be tested for proper pressure regularly during a work shift. A Jarvis pneumatic gun set at 190 psi is sufficient to cause brainstem disruption, which ensures instantaneous insensibility and no chance of recovery (Oliveira *et al.*, 2017, 2018a). However, Kline *et al.* (2019) reported that cattle stunned with a Jarvis pneumatic captive bolt gun (200–210 psi) (1379–1448 kPa) were rendered unconscious instantly even when the brainstem remained intact. Furthermore, a similar study comparing bolt lengths in the Jarvis found that the longer bolt (17.8 cm versus 15.2 cm and 16.5 cm) caused increased visible brain damage (Wagner *et al.*, 2019). This study showed that there was no significant impact of the longer bolt length on specified risk material (SRM) dispersion from the brain. These two studies show that brainstem disruption is not necessary to induce instantaneous insensibility as long as the operator is using a high-powered pneumatic

penetrating captive bolt. A pneumatic stunner should have its own dedicated compressor. Running the stunner off the same system that runs other air tools in the abattoir may result in insufficient air pressure. This is especially a problem if many other tools are operated at the same time.

Hand-held

Hand-held captive bolt guns are powered by a blank cartridge. The gun is held in the operator's hand and is fired with a trigger. Hand-held captive bolt guns are commonly used in small abattoirs, or are a back-up gun in abattoirs using a pneumatic stunner. Hand-held captive bolt guns can be classified as either in-line, pistol-style, or long-handle. An in-line gun consists of two main interconnected pieces, which form a linear-shaped gun (Fig. 10.2). A pistol-style gun looks similar to a pistol firearm with a squeezable arched trigger and perpendicular handle (Fig. 10.3). A long-handle consists of a pistol-type captive bolt with an extended handle. The long-handle without a trigger is fired after the end of the barrel comes in contact with the animal. A small amount of force is required to fire this gun. The operator must always be careful not to tap the gun end on a surface that may cause it to fire unintentionally. A long-handle, hand-held captive bolt gun is used in situations where an animal may be out of reach. This type of device may also be used to humanely euthanize a non-ambulatory animal, or downer, in the abattoir lairage. Placement accuracy is critical for delivering an effective stun with a hand-held captive bolt gun, because it is less powerful than many pneumatic captive bolt guns.



Fig. 10.1. A pneumatic penetrating captive bolt gun. (Photo courtesy of Temple Grandin.)



Fig. 10.2. A hand-held in-line penetrating captive bolt gun. (Photo courtesy of Dennis William Willson.)

Non-penetrating captive bolt gun

Non-penetrating captive bolt guns have a mushroom-shaped bolt that does not fully penetrate the animal's head. It induces unconsciousness with a strong concussive force. Non-penetrating captive bolts are often used at abattoirs for halal slaughter of cattle. This type of gun may allow for the revival of an unconscious animal, especially if the animal is not bled immediately after stunning. As a general rule, the stun-to-stick interval should not exceed 60 s (AVMA, 2016). Depending on the type of gun, the non-penetrating force may or may not cause a skull fracture. Accurate placement of the stun is very important when using a non-penetrating captive bolt. There is a much smaller margin for error when using a non-penetrating captive bolt gun. The non-penetrating captive bolt must be placed perfectly perpendicular to the animal's forehead. A non-penetrating captive bolt is most effective when it makes a dent in the forehead of a bovine.

There is concern about the effectiveness of non-penetrating captive bolt guns for certain species. Recent studies in cattle report that a non-penetrating captive bolt gun is less effective at inducing instantaneous insensibility than a penetrating captive bolt gun. One study assessed zebu bulls' brains with portable electroencephalography (EEG) after the animals were stunned with a penetrating pneumatic captive bolt stunner or non-penetrating stunner



Fig. 10.3. A hand-held pistol-style penetrating captive bolt gun. (Courtesy of Jarvis Bunzl Processor Division.)

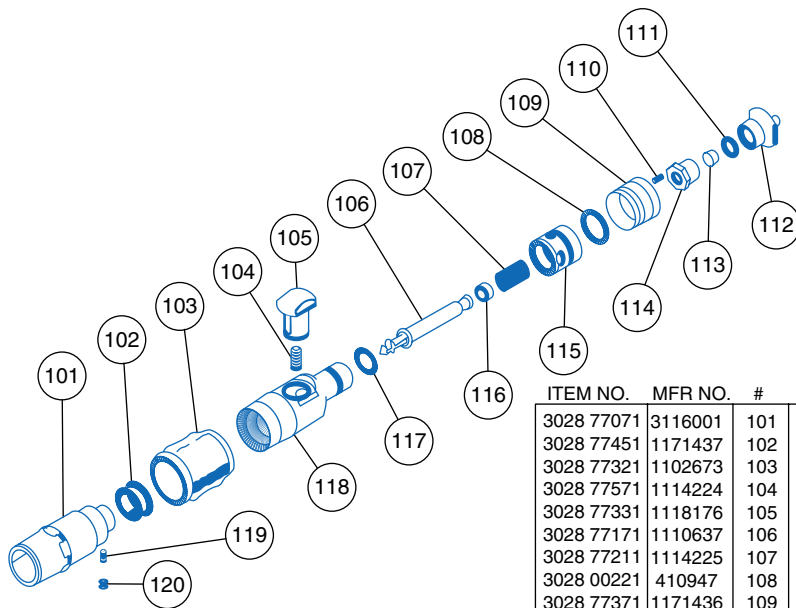
(Gibson *et al.*, 2019). The researchers found that only 82% of the bulls stunned with a non-penetrating captive bolt showed waveforms that indicated complete loss of consciousness, compared with 100% of bulls stunned with a penetrating captive bolt (Gibson *et al.*, 2019). Another study with zebu and crossbred (zebu and European breeds) bulls, steers and cows measured several variables related to stun effectiveness and signs of insensibility after being stunned with a non-penetrating or penetrating captive bolt. Oliveira *et al.* (2018b) reported that 99% of bulls stunned with a penetrating captive bolt immediately collapsed and only 12% required a second shot. In contrast, only 91% of bulls stunned with a non-penetrating captive bolt immediately collapsed and 29% required a second shot. Additional behaviours related to sensibility such as the righting reflex, eyeball rotation and response to nostril stimulations were observed more often after non-penetrating captive bolt stuns compared with penetrating captive bolt stuns (Oliveira *et al.*, 2018b).

Maintenance and Repair

The condition of a captive bolt gun reflects the level of care it has received. All captive bolt guns and stunning devices should be completely disassembled and cleaned every day. Supplies and procedures should be used according to the manufacturer's recommendations. Personnel should be familiar with each of the pieces and inner workings of the captive bolt gun (Fig. 10.4). Figure 10.5 shows an exploded parts diagram of an in-line penetrating captive bolt gun with labelled parts. Wire brushes are common tools used for cleaning (Fig. 10.6). Specific tools for cleaning may vary depending on the type of gun and



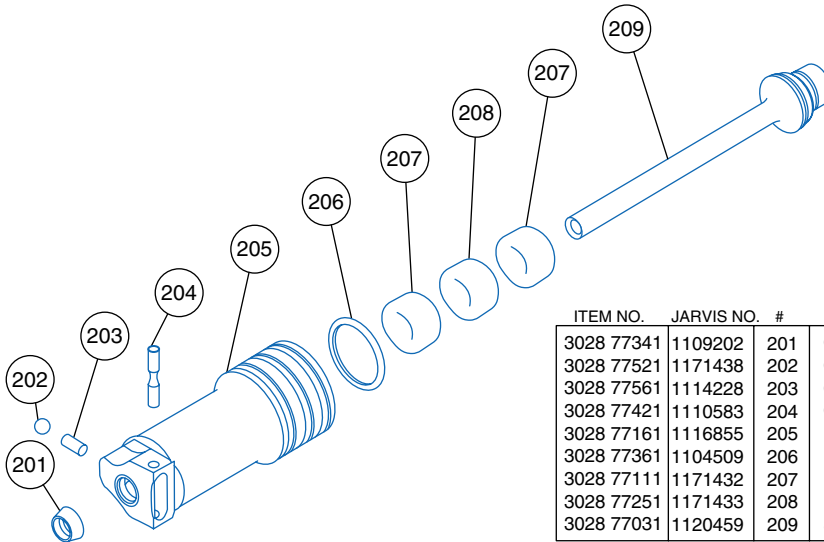
Fig. 10.4. Disassembled cartridge-fired in-line captive bolt gun. (Courtesy of Dennis William Willson.)



**JARVIS
PAS-CS 25S
Replacement parts**

△ See page 33 for Safety & Maintenance Instructions.

ITEM NO.	MFR NO.	#	DESCRIPTION	QTY
3028 77071	3116001	101	BREECG HOUSING	1
3028 77451	1171437	102	EXTRACTOR .25 CALIBER	1
3028 77321	1102673	103	BREECH COVER	1
3028 77571	1114224	104	TRIGGER SPRING	1
3028 77331	1118176	105	TRIGGER	1
3028 77171	1110637	106	FIRING PIN	1
3028 77211	1114225	107	FIRING PIN SPRING	1
3028 00221	410947	108	SAFETY O-RING	1
3028 77371	1171436	109	OUTER SAFETY CAP	1
3028 77891	1110006	110	SAFETY ROLL PIN	1
3028 00211	410924	111	PULL LOCK O-RING WASHER	1
3028 77471	11171434	112	FIRING PIN PULL	1
3028 77531	1114227	113	PULL BUFFER	1
3028 77621	1136408	114	PULL BUSHING	1
3028 77351	1171435	115	INNER SAFETY CAP	1
3028 77551	1136409	116	PULL SPLIT BUSH (PAIR)	1
3028 00201	410918	117	SMALL O-RING	1
3028 77101	1116857	118	BREECH CAP	1
3028 78747	1114226	119	PLUNGER SPRING	1
3028 77691	1139086	120	EXTRACTOR PLUNGER	1



ITEM NO.	JARVIS NO.	#	DESCRIPTION	QTY
3028 77341	1109202	201	COLLAR	1
3028 77521	1171438	202	COLLAR BALL	1
3028 77561	1114228	203	COLLAR SPRING	1
3028 77421	1110583	204	COLLAR RETAINING PIN	1
3028 77161	1116855	205	BARREL/NOSEPIECE STD	1
3028 77361	1104509	206	BARREL LOCK WASHER	1
3028 77111	1171432	207	BLACK BUFFER, HARD	2
3028 77251	1171433	208	RED BUFFER, SOFT	1
3028 77031	1120459	209	STUNNING ROD BOLT, STD	1

Fig. 10.5. Diagram of disassembled cartridge-fired in-line captive bolt gun. (Courtesy of Jarvis Bunzl Processor Division.)



Fig. 10.6. An example of cleaning tools that can be used to regularly clean and maintain a captive bolt gun. (Courtesy of Dennis William Willson.)

manufacturer. In addition to cleaning, the bumpers should be checked for signs of wear (Fig. 10.7). Other parts that should be examined include the firing pin for signs of misalignment and any cracks or blemishes that may cause a malfunction. A review of cattle stunning with a penetrating captive bolt stressed the importance of regular cleaning and maintenance (Kamenik *et al.*, 2019). When there is a malfunction, the gun should immediately stop being used and thoroughly examined to find and fix the cause of the malfunction. The most common reasons for poor performance of a captive bolt gun are related to the lack of maintenance and cleaning of the device, as well as damp cartridges (Grandin, 2002). The second author has observed the bad practice of storing cartridges overnight on the damp windowsill of a kill floor. This resulted in frequent misfires.

Captive bolt guns should be tested frequently with a testing stand (Fig. 10.8). The test stand must be placed on a solid surface such as a concrete floor or sturdy steel work bench to obtain an accurate reading. Placing the test stand on a flimsy plastic cart resulted in inaccurate readings. Regular testing ensures that the gun is operating at the recommended settings. The bolt velocity should be 55 m/s for steers and cows and 70 m/s for bulls (Gregory, 2007; Gregory *et al.*, 2007). In addition, high-speed processing lines should rotate the use of multiple cartridge-fired captive bolts to prevent overheating, which can degrade the hitting power (Grandin, 2019).

Operator Training and Safety

Worker safety is of critical importance when working with captive bolt guns. All personnel should be thoroughly trained and familiar with the equipment before operating a captive bolt gun. Training should be administered to all employees who will

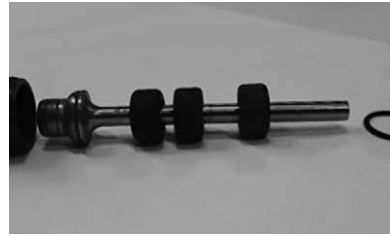


Fig. 10.7. New, intact bumpers on a penetrating hand-held captive bolt gun. Be sure to check bumpers for wear regularly. The purpose of the bumpers is to automatically retract the bolt after each shot. If they become worn the rod may get stuck in the animal's head. (Courtesy of Dennis William Willson.)



Fig. 10.8. A Jarvis brand hand-held captive bolt gun testing station. (Courtesy of Dennis William Willson.)

be operating or near the stunning area. Often, training is administered on a regular basis to serve as safety updates and refreshers.

Gunshot

Accurate shot placement is of the utmost importance when stunning an animal (Schiffer *et al.*, 2017). In addition, it is important to use the right size, gun calibre and bullet, especially for very large animals (Shearer, 2018). The UK's Humane Slaughter Association (HSA) recommends ammunition that can generate a muzzle energy of at least 200 joules for killing large or mature animals (Humane Slaughter Association, 2019). When the same calibre of ammunition is used, a rifle is almost always superior to a pistol (AVMA, 2019). Bullets come in various qualities. All bullets are not the same, even though they may be the same calibre. Never use .22 shorts to stun an animal. Do not put the gun directly against the forehead of the animal. Hold the muzzle between 20 cm to half a metre away from the target when using a firearm, to minimize the risk of gun barrel explosion.

Box 10.1. Tips for maintaining captive bolt guns

(from Bildstein, 2009)

- The gun must be cleaned every day it has been fired. Clean it the same way as a firearm.
- Use gun oil and gun cleaner. Do not use machinery grease, white oil, or WD-40®.
- Do not get the captive bolt gun wet.
- Use a wire brush to polish the piston end of the bolt every time the stunner is cleaned.
- Replace the bumpers if they are cracked or stiff. This will prevent the bolt from sticking in the head.
- Number the guns and do not mix the parts. Each gun wears differently.
- Have plenty of spare parts for replacement of worn or broken parts.
- Store cartridges in a dry place. Damp cartridges are a common cause of underpowered shots (Grandin, 2002).

Box 10.2. Safety tips for workers

(from www.grandin.com)

- Safety equipment should be worn when handling and operating a captive bolt gun. This includes, but is not limited to, a protective vest (chest and groin protection), hard hat, ear protection, eye protection and gloves.
- Cartridge-fired stunners must always be uncocked before they are set down.
- Never throw a cartridge-fired stunner to another person.
- Cartridge-fired stunners must always be kept unloaded when being carried or stored.
- Good maintenance is essential on pneumatic stunners to prevent excessive recoil, which can cause strain and injure the operator's hands, arms or back.

Additional information regarding stunning with firearms can be found in the American Veterinary Medical Association (AVMA) *Guidelines for the Euthanasia of Animals* (2020 Edition), the AVMA *Guidelines for Humane Slaughter* (2016 Edition) and the AVMA *Guidelines for the Depopulation of Animals* (2019 Edition).

Restraint

Restraint methods that cause suffering

The OIE guidelines (2019) for animal welfare state that methods of restraint that cause avoidable suffering should not be used. Methods of restraint that should never be used include:

- lifting or suspending a sensible animal by the feet or legs (except for poultry);
- mechanical clamping of a mammal's feet or legs;
- breaking bones;
- cutting tendons to immobilize;
- blinding; or
- severing the spinal cord to paralyse the animal.

Move animals quietly into restrainers

Animals should calmly enter a restrainer or stun box. If animals are baulking, observe why they are baulking, instead of using an electric prod. Poor lighting, shadows, slippery floors, contrast in flooring, air blowing in the face and visual distractions such as flapping objects or people can cause an animal to refuse to move (Grandin, 1996, 1998a). Simple fixes such as installing indirect lighting at the restrainer entrance, non-slip flooring and using cardboard to block the animals' vision reduces baulking and percentage of vocalizations due to electric prod use (Grandin, 2001). Equipment designers and animal handlers should be trained in using behavioural principles of low-stress livestock handling to control animals. The restraint device should be designed to provide optimal pressure on the sides of the animal, which keeps the animal calm and easy to handle. Other designs, including a knock box and headholder, can also be used with careful design considerations. (See Chapter 6 for more information about restraint.)

Stun Placement and Accuracy

One of the most important factors of humane slaughter is accurate stun placement. The correct placement of a stun varies, based on the species of animal. The exact placement may also vary slightly depending on the breed or head shape of a specific animal. In cattle, the preferred position for either captive bolt or gunshot is in the middle of the forehead (Fig. 10.9). The poll position should only be used if the forehead cannot be reached. When the poll position is used, the shot is located in the hollow behind the animal's poll.

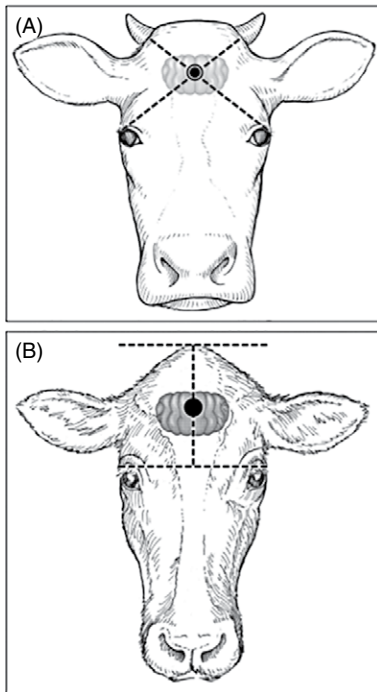


Fig. 10.9. Diagram of the anatomical shot placement for cattle. The shot should be placed at the intersection of two imaginary lines, each drawn from the outside corner of the eye to the centre of the base of the opposite ear (A). Alternatively, in long-faced cattle or young-stock (B), a point on the midline of the face that is halfway between the top of the poll and an imaginary line connecting the outside corners of the eyes can be used. (Adapted from the AVMA *Guidelines for the Humane Slaughter of Animals*, 2016 edition.)

Determining Insensibility

An animal should be rendered unconscious and insensible after one stun (EFSA, 2013a; CFR, 2018a). When captive bolt stunning is performed correctly, a single shot will cause immediate collapse with loss of posture, no rhythmic breathing, no righting reflex, no vocalizations, no corneal reflex and no menace reflex (AVMA, 2016, 2019). Gouveia *et al.* (2009) found that stunning efficiency with a captive bolt was greater in female animals compared with males (greater than 12 months of age), decreased with animal age in general and was better in dairy animals compared with beef animals. Signs of kicking should not be used to determine if an animal is conscious (Bartz *et al.*, 2015). An animal's spine will continue to fire signals to the walking circuit that will cause rhythmic movements related to walking even after the loss of consciousness. A properly stunned, unconscious animal may exhibit sideways head movements or post-stun leg paddling (Terlouw *et al.*, 2015). The observation of an animal that is kicking does not mean that an animal is conscious or returning to consciousness. (See Chapters 13 and 14 for more detailed information on determining insensibility.)

Recommendations for Other Species

The choice of captive bolt gun or firearm and placement depends on the species and field conditions. Delivering an effective stun safely with one shot should always be the number one priority. A penetrating captive bolt gun or gunshot to the middle of the forehead should always be used for cattle, especially mature bulls and aged animals, which have thickened frontal bones. Non-penetrating captive bolt guns have been found to be effective for euthanizing neonatal piglets, kid goats and lambs (Grist *et al.*, 2018a,b,c), as well as for young Holstein veal calves (Bartz *et al.*, 2015) and alpacas (Gibson *et al.*, 2015).

Sheep and goats

Sheep and goats can be stunned with either a captive bolt gun or firearm. There are three acceptable points of entry on sheep: the front of the head; the top of the head; and the back of the poll (Fig. 10.10). When delivering a forehead shot, position the gun so that entry is 2.0 cm above the eyes (Grandin, 2015). If using a gunshot, the ideal shooting

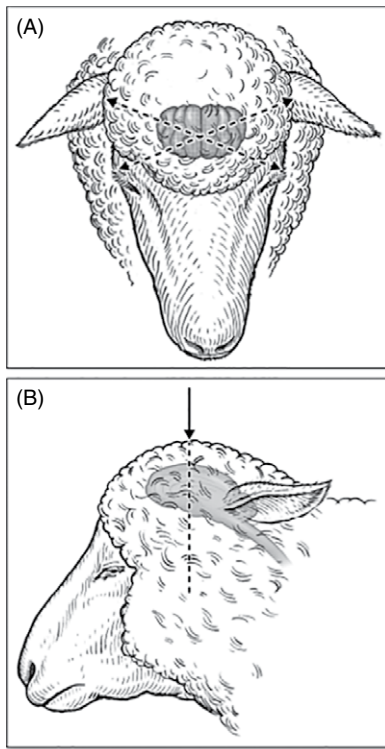


Fig. 10.10. Diagram of the anatomical shot placement for sheep. For polled sheep (A), the proper site is at or slightly behind the poll (B) or aiming toward the angle of the jaw or base of the tongue may be used. (Adapted from the AVMA *Guidelines for the Humane Slaughter of Animals*, 2016 Edition.)

position for sheep is the top of the head at the midline of the skull, pointing straight down at the throat. In horned sheep, the most effective shot is behind the poll, which allows the projectile to avoid the extra bone mass created by the horns that cover the area in front of the brain (Grandin, 2015). Goats can be stunned just behind the poll with a captive bolt gun or firearm (Fig. 10.11). Plummer *et al.* (2018) verified that a penetrating captive bolt can be fired perpendicular to the skull at the poll position. In addition, Collins *et al.* (2017) examined the brains of goats stunned at the poll with a penetrating or non-penetrating captive bolt gun, using MRI and CT scans. The researchers reported severe skeletal and soft-tissue damage after impact with both types of captive bolt guns, suggesting that non-penetrating captive bolt stunning may be an acceptable method for goats.

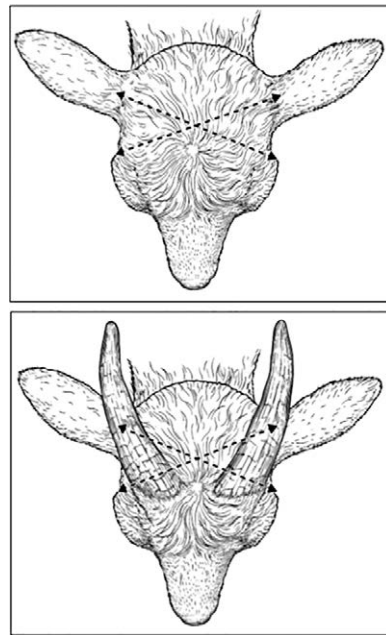


Fig. 10.11. Diagram of shot placement for goats. The optimal position is determined by using the intersection of two imaginary lines, each drawn from the outside corner of the eye to the centre of the base of the opposite ear with the projectile directed towards the back of the throat. (Adapted from the AVMA *Guidelines for the Humane Slaughter of Animals*, 2016 Edition.)

Swine

Pigs are stunned in a similar fashion as cattle. Anderson *et al.* (2019) found that a frontal application of a penetrating captive bolt was the most effective position for stunning pigs (Fig. 10.12). The Zephyr-E, a non-penetrating captive bolt gun, has been very successful at rendering piglets (3–9 kg) insensible (Casey-Trotts *et al.*, 2014). Another study found that a non-penetrating captive bolt was effective for piglets (Grist *et al.*, 2018b). In small piglets, a standard non-penetrating captive bolt will crush the brain.

Horses

Horses that are slaughtered are commonly stunned with a captive bolt or a firearm. A frontal shot placement is recommended (Fig. 10.13). Gibson *et al.* (2015) reported that the use of a .22 calibre long rifle with hollow point ammunition was an effective method of stunning equines.

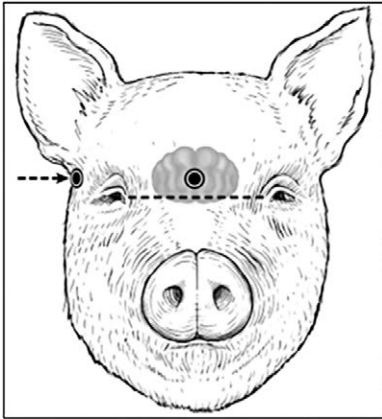


Fig. 10.12. Diagram of the two anatomical shot placements for pigs. The two positions include frontal and temporal. (Adapted from the AVMA *Guidelines for the Humane Slaughter of Animals*, 2016 Edition.)

Water buffalo

Water buffalo are often stunned with either a captive bolt or a firearm. Gregory *et al.* (2009) found that shooting water buffalo in the frontal position with a captive bolt gun was not always effective. They also stated that poll shooting can be effective but requires accurate placement to ensure that the animals are not shot through the spinal cord instead of the brain. A recent ballistics test showed that increased impact energy of a penetrating captive bolt or free projectiles from a firearm does not always correlate to higher perforation rate in the animal's skull, which led to a newly developed .357 Magnum stunning device specifically for water buffalo (Gardon *et al.*, 2018).

Cervids

A deer's brain is situated high in the skull. A captive bolt or gunshot should be placed 2.0 cm above the

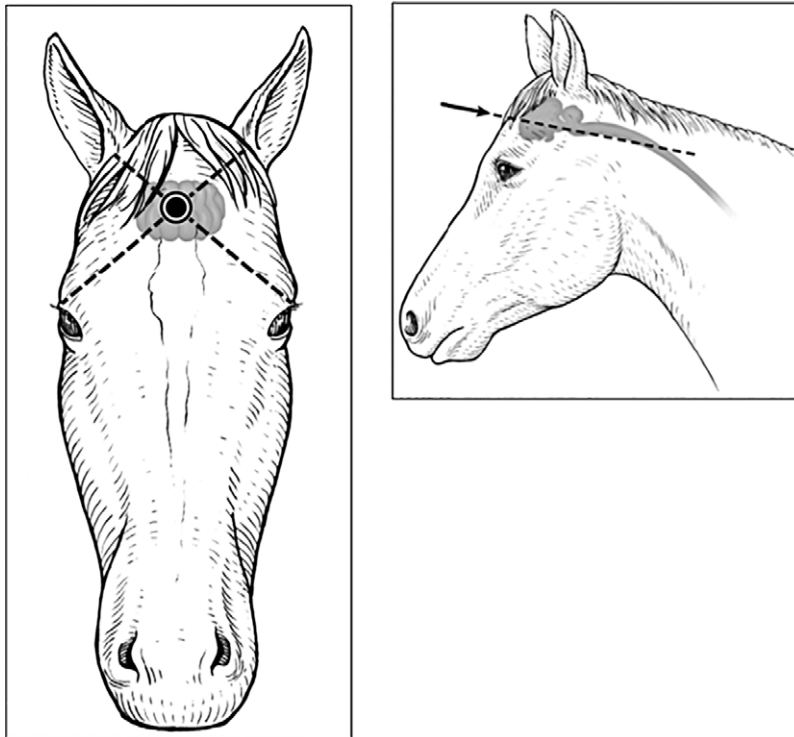


Fig. 10.13. Diagram of shot placement for horses. (Adapted from the AVMA *Guidelines for the Humane Slaughter of Animals*, 2016 Edition.)

intersection of an imaginary X drawn on the forehead, with each line starting at the inside corner of the eye and the base of the antler on the opposite side (Grandin, 2015). A gunshot to the back of the head or upper cervical region may also be sufficient to render deer and elk instantaneously insensible. Deer shot in the brain with a .223 calibre rifle from 10 m to 125 m died immediately from severe tissue damage to brain or spinal tissue (DeNicola *et al.*, 2019).

Poultry

The US Humane Slaughter Act of 1978 does not cover poultry; however, the Humane Slaughter of Livestock Regulations includes good commercial slaughter practices (CFR, 2018b). The regulations in Europe (EFSA, 2013b), Canada and Australia definitely include poultry in their Humane Slaughter regulations. A laboratory-made prototype of a pneumatic captive bolt gun operated most effectively with a minimum of 6 mm bolt diameter with an 872 kPa air-line pressure and a 10 mm penetration depth for effectively stunning broiler chickens (Raj and O'Callaghan, 2001). On turkeys, a non-penetrating captive bolt gun may be sufficient to induce immediate insensibility. A study by Gibson *et al.* (2018) used EEG to examine brain activity in turkeys stunned with one of three different concussive, non-penetrating captive bolt guns. The researchers found that all three types of non-penetrating captive bolt guns were effective at inducing unconsciousness if the shot was placed correctly and the power load performed as described in the manufacturer's specifications. Similarly, Woolcott *et al.* (2018) evaluated the effectiveness of two different non-penetrating captive bolt guns for stunning turkeys and found that both types of guns effectively caused immediate insensibility by traumatic brain injury.

Guinea pigs

Guinea pigs are often slaughtered for food in certain parts of the world. After a comparison of multiple stunning methods, captive bolt was deemed the most humane, effective and practical (Limon *et al.*, 2016). Cervical neck dislocation resulted in 97% of the guinea pigs showing behavioural or cranial/spinal responses indicative of possible suffering; therefore, this method should not be recommended (Limon *et al.*, 2016).

USDA Regulatory Actions Provide Insight into Stunning Problems

Livestock welfare problems at slaughter can be identified by looking at humane handling enforcement actions. The goal of determining welfare problems at slaughter is understanding the challenges so that practical solutions can be found. In 2017, 104 humane handling enforcement actions were issued to abattoirs by the FSIS. The USDA defines a very small abattoir as an establishment having up to nine employees or less than \$2.5 million in annual sales. A small abattoir has 10–499 employees and a large abattoir has 500 or more employees (CFR, 1996). The FSIS takes official enforcement action against abattoirs found to be in violation of the Humane Slaughter Act of 1978 (USC, 2017), as regulated by the Humane Slaughter of Livestock Regulations (CFR, 2018a). A violation results in a notice of intended enforcement (NOIE) or a suspension by the FSIS. An NOIE is a warning that an infraction must be addressed. Failure to correct the non-compliance results in suspension. Inspection services cease during a suspension and the abattoir may be closed for hours or days. In 2017, 18% (19 of 104) of FSIS humane handling enforcement actions were NOIEs, 59% (61 of 104) were suspensions and 23% (24 of 104) were reinstatements of suspension. A reinstatement of suspension occurs when the establishment fails to take sufficient corrective action or commits another violation. The FSIS issues a deferral of the NOIE or abeyance of the suspension when evidence of appropriate corrective action and preventive steps has been established. The FSIS district office must approve a written response by the establishment before inspection services resume. A complete summary and discussion of the 2016 and 2017 humane handling enforcement actions can be found as a written article in the *National Provisioner* (Baier *et al.*, 2018).

Stunning violations summary

Stunning issues at very small abattoirs are the reason for the majority of FSIS humane handling enforcement actions (Table 10.1). In 2017, 88% (92 of 104) of enforcement actions were related to stunning, while the remaining 12% (12 of 104) were related to handling. Of the 92 enforcement actions related to stunning, 72% (66 of 92) were issued to very small abattoirs, 17% (16 of 92) to small abattoirs, and 11% (10 of 92) to large abattoirs.

Table 10.1. Summary table of 2017 USDA FSIS humane handling enforcement actions.

Abattoir size	Handling	Reason for enforcement action						
		Stun placement			Restraint	Equipment failure	Knife (ritual)	N/A
		CB	Gun	Electrical				
Very small	6	22	19	3	18	2	1	1
Small	3	6	3	1	0	3	1	2
Large	3	6	0	0	3	1	0	0

The designation of N/A was used when the main reason for the enforcement action was not stated. CB: captive bolt

Stunning was performed either electrically or mechanically by captive bolt or gunshot. Of the 92 enforcement actions related to stunning, 41% (38 of 92) involved captive bolt stunning and 30% (28 of 92) involved gunshot stunning. In addition, ten incidents involved captive bolt stunning followed by gunshot, and four incidents involved gunshot stunning followed by captive bolt. Two reports did not indicate whether the mechanical stunning violation involved captive bolt or gunshot. Finally, eight incidents involved electrical stunning and two incidents involved bovine halal knife slaughter.

Reasons for stunning problems

Stunning issues are due to poor placement, improper restraint and handling, or equipment failure. In 2017, 70% percent (64 of 92) of FSIS humane handling enforcement actions were due to poor placement of a captive bolt, gunshot, electrical stunner or problems with the cutting method for non-stunned religious slaughter, and 23% (21 of 92) were due to improper restraint (Fig. 10.14). Six reports stated equipment failure as the reason for the stunning issue, including four incidents of captive bolt failure, one occurrence of electrical failure and one gunshot failure.

Twenty years ago, Grandin (1998b) reported that maintenance was the number one reason for misfires and ineffective stuns in US abattoirs. A low incidence of equipment failure in 2017 indicates that the abattoirs are now doing a much better job at maintaining this equipment. This is due to both increased enforcement from the USDA and welfare auditing by meat-buying customers. This is why poor placement has become a main reason for ineffective stuns. In 2017, needing more than two stun attempts to render an animal insensible accounted for 61% (63 of 104) of FSIS humane handling enforcement actions, including 57% (36 of 63) bovine, 32% (20 of 63)

Reason for enforcement action by USDA-FSIS in 2017

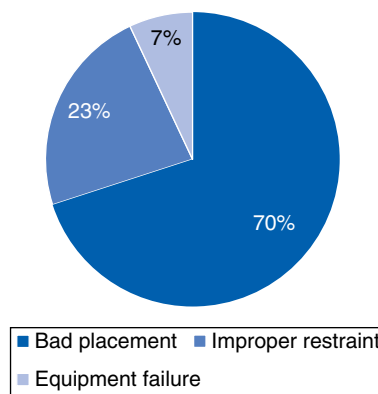


Fig. 10.14. A pie chart graphic summarizing the main reasons for the enforcement actions taken by the USDA FSIS in 2017. Action was taken in relation to three different events, including poor placement, improper restraint or equipment failure. Bad placement involves an inaccurate stun performed by the stunning operator, while equipment failure is related to the stunning device not working properly for a reason unrelated to the stun placement or accuracy. An improper restraint involves an animal that was not sufficiently held to ensure that a correct stun was performed.

porcine and 6% (4 of 63) ovine; 5% (3 of 63) did not list the species. In the UK, a gross examination of cattle heads shot multiple times showed that inaccurate placement was the determining factor in 83% (10 of 12) of cases where a second stun was delivered (Grist *et al.*, 2019). An ineffective stun occurs for several reasons (Box 10.3).

Auditing Stunning Practices

Abattoirs that have an effective, systematic approach to good captive bolt stunning practices

Box 10.3. Reasons for ineffective stuns

- **Animals slip in the stun box**, causing the animal to panic and thrash in the stun box. A panicked animal makes an accurate stun difficult. This can easily be fixed by installing non-slip flooring. Excellent choices for non-slip flooring include steel rods in a 20 cm × 20 cm diamond-pattern, a grooved-concrete floor, woven tyre mats, or steel rods that are welded flush to the floor. Chequered metal plates or rough broom concrete finishes are not adequate. Cattle will slip on these.
- **Rough handling** such as yelling, using an electric prod or hitting an animal with a mechanical handling device such as a rattle paddle occurs while moving animals towards the stun box. Bad handling can be corrected by training employees in low-stress livestock handling techniques. Use of mechanical handling aids should be secondary to good facility design and an understanding of the use of behavioural principles to get animals to cooperate.
- **The operator chases the head** in the stun box. Operators should be trained to exercise patience and allow the animal to calm down before delivering the stun.
- **Overloading the system** can occur if the speed of production is being pushed too hard or the abattoir is understaffed. Overloading the system is a management issue. Understaffing without slowing production speed leads to overworked, frustrated employees who use rough handling. Equipment should not be overworked, especially cartridge-fired captive bolt guns. Problems with overloading a system can occur in both small and large abattoirs. It is a function of both equipment design and the number of employees operating the equipment.

will usually average about 96–98% of the animals being rendered insensible with a single shot (Grandin, 2005). Some plants will routinely shoot animals twice to ensure that they remain insensible, as a security knock. When the plant is being evaluated for stunning, the auditor or inspector should inspect the animal before the second shot is applied. The operator has to be able to demonstrate that they are capable of rendering 95% or more of the animals insensible with a single shot (Grandin, 2017). An experienced operator can easily achieve this (Atkinson *et al.*, 2013). The North American Meat Institute (NAMI) guideline allows 5% extra shots to enable the stunner operator to use an extra shot on a questionable animal (Grandin, 2017). Operators who attempt to never take an extra shot are more likely to have problems with return to sensibility (Grandin, 2019). Both the USDA and NAMI Guidelines have zero tolerance for starting invasive procedures such as skinning or leg removal on an animal showing signs of return to sensibility (CFR, 2018a; Grandin, 2017).

Stunner training resources

Training employees in basic principles of low-stress handling of livestock reduces baulking and facilitates animal movement, which increases efficiency. Dr Temple Grandin's website, Grandin.com, contains free resources for abattoir managers developing

a livestock handling training programme for their employees. In addition, managers should make use of a free e-learning series posted at www.hsa.org.uk/publications/online-guides by the UK's Humane Slaughter Association about a variety of humane livestock slaughter topics. Certification courses in livestock welfare auditing, such as those offered by the Professional Animal Auditor Certification Organization (PAACO) in the USA, provide an opportunity for animal handlers to acquire professional-level expertise and credentials in evaluating livestock welfare at slaughter. Many countries have similar animal welfare training courses. Incentive programmes that reward employees who consistently demonstrate humane livestock handling skills should also be considered by abattoir managers.

Conclusion

Penetrating captive bolt is more effective than non-penetrating. Non-penetrating should not be used on bulls or mature pigs (AVMA, 2020). Captive bolt guns should be frequently cleaned and maintained to ensure that the devices perform properly. All employees should receive training regularly and always use caution when operating a captive bolt. Employee safety is the most important aspect when working with any type of gun. Accurate stun placement and adequate restraint are critical factors when

efficiently and humanely stunning an animal with a captive bolt. Continuous improvement should be a consistent goal. Facilities and operators should stay informed and aware of new trainings or guidelines that may help improve any stunning-related practices or devices.

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11

Religious Slaughter and How to Improve Welfare During Both Kosher and Halal Methods

TEMPLE GRANDIN^{1*} AND ERIKA VOOGD²

¹*Department of Animal Science, Colorado State University, USA;*

²*Voogd Consulting, Chicago, Illinois, USA*

Summary

There are three main issues when religious slaughter without stunning (kosher or halal) is discussed from the perspective of animal welfare. The first issue is the restraint method used to hold the animal in position and the second issue is the question of pain during the cut. The third issue is the time required to lose consciousness after the cut and possible distress during this period. Good cutting technique, well-designed restraint equipment and attention to details of the procedure will reduce animal welfare problems in both livestock and poultry. Many Muslim religious authorities will accept pre-slaughter stunning of livestock and poultry. Full reversible electrical stunning is preferred. The main religious concern is that the animal must be alive at the time of slaughter.

Learning Objectives

- Assessment of both restraint and cutting methods to improve animal welfare.
- Understand the design and operation of restraining devices.
- Methods to improve the cutting method to reduce the time the animal remains conscious.
- Learn about the different pre-slaughter stunning methods that may be permitted by religious authorities.

Introduction

Slaughter without prior stunning is a controversial subject from an animal welfare standpoint. Most

European Union (EU) countries, the OIE (World Organisation for Animal Health), and the USA, UK, Canada, Brazil, France and many other countries permit slaughter without stunning (Defra, 2015; Law Library of Congress, 2018). Allowing slaughter without stunning enables Jews and Muslims the freedom to practise this aspect of their religious beliefs. In Belgium, slaughter without stunning has been banned in some regions (Law Library of Congress, 2018). A discussion of all the religious freedom issues is beyond the scope of this chapter. When listing exceptions to a requirement that slaughter can only be conducted after stunning, legislation and guidelines often use the terms 'religious' or 'ritual' slaughter to refer to halal (Muslim) or kosher (Jewish) slaughter conducted without pre-slaughter stunning. Some halal slaughter is undertaken with either pre- or post-slaughter stunning. The purpose of this chapter is to provide practical guidance to people who are actually engaged in religious slaughter or otherwise involved, such as veterinarians, students, abattoir managers and inspectors. This guidance will help improve animal welfare during slaughter without prior stunning.

Some of the worst animal welfare issues that occur during religious slaughter are caused by sloppy procedures. It is the authors' opinion that religious slaughter can be done with an acceptable level of animal welfare, but it requires much greater attention to the details of procedure than conventional slaughter with stunning (Grandin, 1994; Grandin and Regenstein, 1994). Fortunately, many religious authorities will allow certain types of pre-slaughter

* Email: cheryl.miller@colostate.edu

stunning methods which will provide the highest level of welfare during halal slaughter. This chapter has four parts: (i) welfare during restraint for slaughter without stunning and assessment of restraint methods; (ii) welfare issues associated with the neck cut; (iii) methods to reduce the time the animal remains conscious; and (iv) use of permitted stunning methods. A major issue is that halal or kosher slaughter requires the animal to be alive at the time of the neck cut. There will be a discussion of how 'being alive' is defined.

Three Major Welfare Issues During Slaughter Without Stunning

Holding cattle, sheep or goats in position for slaughter without stunning requires restraining a fully conscious animal. There are three major welfare issues associated with either halal or kosher slaughter that is performed without pre-slaughter stunning. They are: (i) restraint and handling prior to the neck cut; (ii) possible pain during the neck cut; and (iii) possible distress during the time required for the animal to lose consciousness (Velarde and Dalmau, 2018). Some of the worst welfare problems observed by the first author are highly stressful methods of restraint. Some of the serious problems are excessive electric prod use and a high percentage of cattle bellowing. Vocalization of cattle during handling and restraint is associated with physiological measures such as cortisol (Dunn, 1990; Hemsforth *et al.*, 2011). The OIE (2019), the State of Israel (IVSAH, 2017) the UK government's Department for Environment, Food & Rural Affairs (Defra, 2015), the EU and the DIALREL Report (2010) recommend avoiding highly stressful methods of restraint such as suspending livestock by the leg or legs, or dragging live animals. The OIE (2018) guidelines state:

Methods of restraint causing avoidable suffering should not be used in conscious animals because they cause severe pain and stress: i) suspending or hoisting animals (other than poultry) by the feet or legs; ...

Although the OIE standards are guidelines, they provide a basis for the formulation of national legislation to comply with OIE standards. An Italian study showed that small ruminants in a mechanical rotating box struggled for a shorter period of time compared with animals that were suspended by a rear leg (Novelli *et al.*, 2016). In the USA, there is a

regulatory exemption which makes stressful restraint methods such as shackling and hoisting of conscious animals legal. The regulation, as cited by the Food Safety Inspection Service (FSIS) of the US Department of Agriculture (USDA), states: 'In order to protect freedom of religion, ritual slaughter and the handling and preparation of livestock for ritual slaughter are exempted from the terms of this chapter' (FSIS, 2011).

This USDA regulation is written into the laws of the USA. From a practical standpoint, the USA has no regulations for restraint of the animal during 'ritual slaughter'. A cutting method that is in accordance with the ritual requirements of a religious faith is deemed humane (USC, 1958). Private industry guidelines in the USA and Canada prohibit shackling and hoisting of conscious livestock (NAMI, 2019). In the USA, most kosher cattle plants have eliminated the shackling and hoisting of conscious cattle. Unfortunately, there are small abattoirs that perform either halal or kosher slaughter that still hoist up conscious sheep and goats by their rear legs. A major factor that has driven improvements is large meat-buying customers demanding improvements. Another driving factor has been reducing injuries to employees caused by struggling hanging livestock.

Restraint

Types of restraint that are acceptable

Livestock can be held in either an upright, inverted or lateral position. Keeping the animals as calm as possible is essential. The principles of good handling and stockmanship are covered in Chapter 6. When a calm animal is slaughtered without stunning, it may lose consciousness sooner (Grandin, 1994; Grandin and Regenstien, 1994). For small animals such as sheep and goats, the conscious animal can be held in an upright position by a person. Sheep can be easily straddled by a person and the head held up for the neck cut. They may become extremely stressed when they are separated from the flock. Sheep were less stressed when they were moved through a V restrainer in a continuous line than when there was a 20 s delay after the neck cut before the next sheep entered the V restrainer (Bates *et al.*, 2014). In cattle, a well-designed upright restraint box was less stressful than a poorly designed rotating box (Dunn, 1990). Velarde and Dalmau (2018) stated that a conscious

animal is more likely to be stressed if it is held on its side or if it is inverted on to its back in a rotary box than if it is restrained in an upright position. Figures 11.1, 11.2, 11.3 and 11.4 all show upright restraint devices for cattle and sheep. Figures 11.5 and 11.6 show rotating boxes for inverted restraint of cattle.

Assessing welfare problems with cattle restraint

Serious welfare problems and stress are occurring if a high percentage of cattle are vocalizing (mooing or bellowing) when they are held in a restraint

device (Dunn, 1990; Grandin, 1998a,b; Munoz *et al.*, 2010). There is also a welfare issue that must be corrected if electric prod use while entering the restraint box is causing a high percentage of cattle to bellow. To assess vocalization, each animal is scored as either silent or vocalizing (Grandin, 1998a,b). When handling and restraint are done with good practices, the percentage of cattle vocalizing in a system with a head restraint should be 5% or less. Tables 11.1, 11.2 and 11.3 show scores for the percentage of cattle vocalizing in systems with good restraint practices and systems with poor restraint practices. A large review of

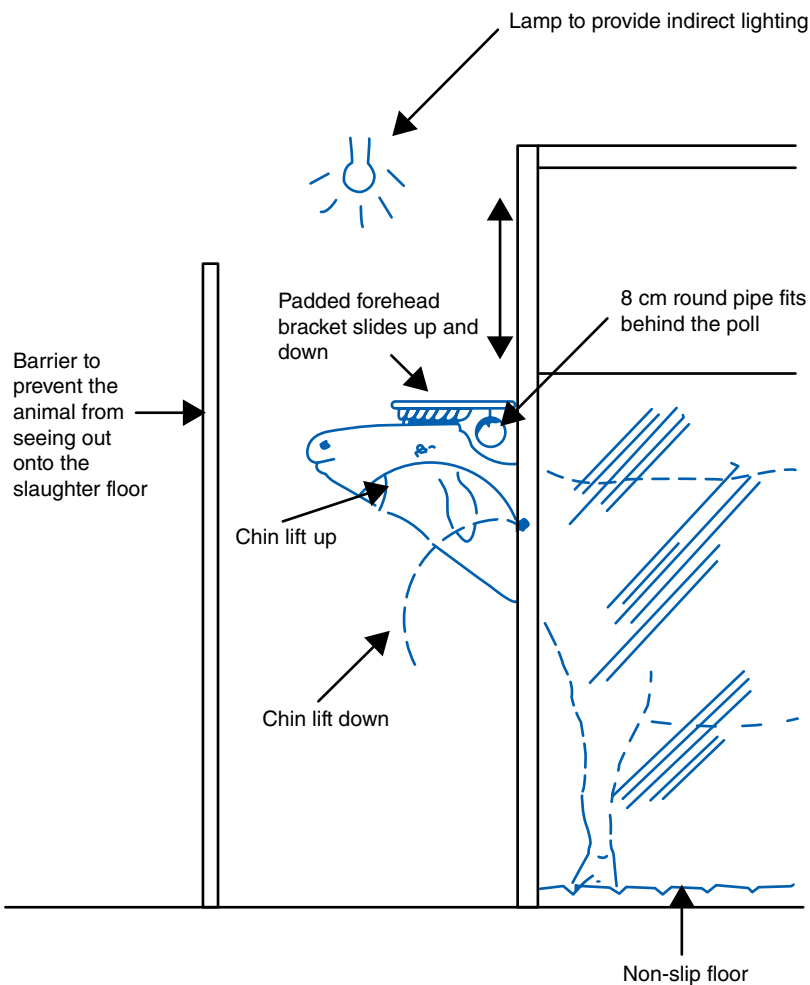


Fig. 11.1. Standing-upright restraint box for kosher or halal slaughter. A solid barrier 1.2 m (4 ft) in front of the headholder prevents incoming cattle from seeing people through the head opening. An overhead light illuminates the area because animals are attracted to a lighted opening. (Diagram courtesy of Temple Grandin.)

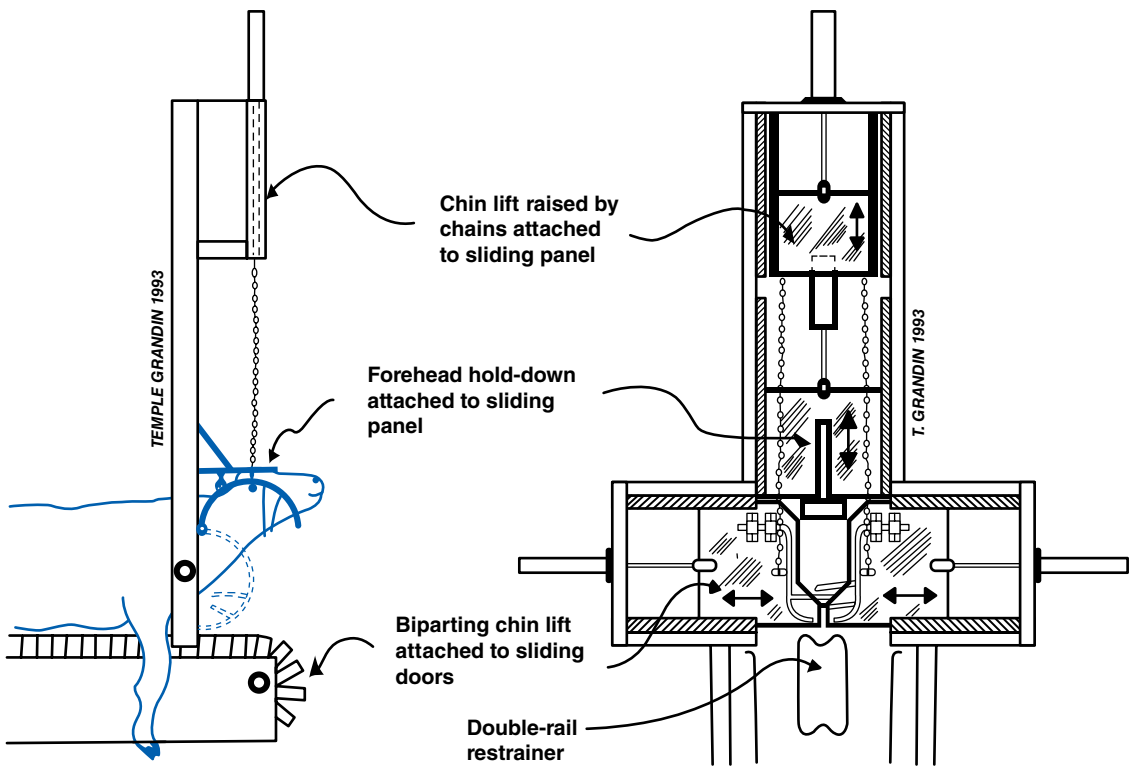


Fig. 11.2. Head-holding device on a centre track conveyor system. A small version can be used for sheep or goats. The chin lift is attached to two biparting sliding doors. (From Grandin, 1993.)



Fig. 11.3. A calf is held in the head restrained position for religious slaughter. Note that the forehead is parallel to the floor and excessive bending of the neck is avoided. The round pipe behind the animal's poll prevents it from pulling its head out. (Photo courtesy of Temple Grandin.)

scientific articles reported that vocalization scoring was considered to be a valid way of assessing cattle welfare in commercial abattoirs (Losada-Espinoza *et al.*, 2018). Chapter 12 on auditing and assessing animal welfare has a more detailed

description of outcome-based numerical scoring for assessing animal welfare during slaughter.

The corrective actions that were implemented to improve the scores for electric prod use, slips/falls and cattle vocalizing shown in Table 11.3 were as follows.

- Discontinued use of high-pressure hose near the lead-up race, because it frightened the cattle.
- Raised open restraint box entrance door to reduce cattle baulking. Cattle may refuse to enter a box if back clearance is too low.
- Stopped banging the metal race with driving aids.
- Avoided jerky movement of the headholder and reduced pressure applied to the head.

Vocalization scoring does not work for sheep

Sheep will vocalize loudly when they are separated from the rest of the flock. This is due to



Fig. 11.4. Small restrainer for holding sheep or goats that is easy to build, based on a design by Westervelt *et al.*, 1976. (Photo courtesy of Spirit of Humane, Joe Regenstein.)

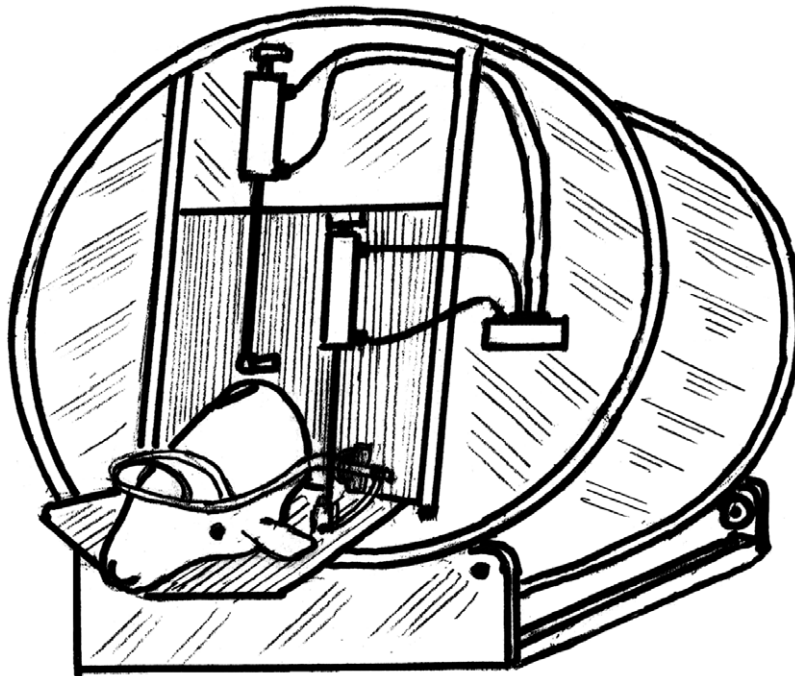


Fig. 11.5. Rotating box for restraint of cattle for kosher or halal slaughter. To prevent struggling, the box should have an adjustable side that will hold the animal snugly when it is rotated. This will prevent the animal from having the sensation of fear of falling. (Diagram courtesy of Temple Grandin.)

separation distress (Price and Thos, 1980). Separation distress (panic) is a separate emotional system from fear (Panksepp, 2011). When sheep are hurt or handled in a stressful manner, they

almost never vocalize. The reason for this is that sheep are one of the most defenceless prey animals (Dwyer, 2004). A sheep that is hurt is more likely to get eaten by a predator if it vocalizes.

A sheep that is separated from the flock vocalizes, because being vocal may help it get back quickly to the safety of the flock.



Fig. 11.6. Rotating box for cattle which holds two cattle. When one animal is in the inverted position, another animal is entering on the other side. The system rotates around a central pivot. Slaughter is conducted promptly after rotation. The vocalization score of approximately 20 Hereford cows was 0%. Washing the throat with the hose may increase stress and increases the length of time that the animal is restrained. (Photo courtesy of Temple Grandin.)

Table 11.1. Percentage of cattle vocalizing in a restraint box used for religious slaughter in abattoirs with good restraint practice.

	Percentage vocalizing	Type of box
Plant 1	2	Upright (Grandin, 2012)
Plant 2	1	Upright (Grandin, 2012)
Plant 3 ^a	4.5	Rotating (Voogd, 2010–2014)

^aPlant 3 score is an average taken from a series of audits. The range was 0% on the best days to 15% on the worst days (Erika Voogd, 2010–2014: data collected during commercial audits of abattoirs conducting religious slaughter)

Table 11.2. Percentage of cattle vocalizing in a restraint box used for religious slaughter in abattoirs with poor restraint practices.

	Percentage vocalizing	Type of box	Reason
Plant 1	23 ^a	Upright	Excessive pressure on the neck (Grandin, 2001)
Plant 2	25	Rotating	Excessive pressure (Bourquet <i>et al.</i> , 2011)
Plant 3	47	Upright	Almost 100% electric prod use on the cattle (Hayes <i>et al.</i> , 2015)
Plant 4	32	Upright	Box was too short and applied excessive pressure to the rear of large cattle (Grandin, 1998a,b)

^aWhen pressure was reduced on the neck, vocalization dropped to 0% (Grandin, 2001).

Vocalization scoring in goats

Goats will vocalize loudly when they are isolated (Price and Thos, 1980) or mistreated. There is a need for research to determine vocalization thresholds for goats.

Monitoring of struggling during restraint

In all species of livestock and poultry, struggling during restraint is a sign of stress. Struggling must be evaluated before, during and after the neck cut. Small ruminants struggle for longer before the cut if they are suspended by one leg than when restrained in a rotating box (Novelli *et al.*, 2016). This is a welfare concern. After bleeding starts, struggling that is caused by convulsions is not a welfare concern, but continued struggling due to stress from the method of restraint, pain from the neck cut or from distress associated with continued consciousness is a concern. Velarde *et al.* (2014) assessed struggling in different types of restraint boxes and reported differences between restraint position in the percentages of cattle that were observed to be struggling after the neck cut. A major problem with this study was that struggling due to discomfort prior to the loss of consciousness and struggling due to post-cut convulsions induced by blood loss were not differentiated. If a conscious animal struggles excessively for a prolonged period of time after the neck cut (more than 15–30 s), it should be stunned. This will prevent needless suffering, even if the meat will be deemed non-kosher or non-halal.

Monitoring electric goad use and falling

Losada-Espinoza (2018) reported that scoring of falling during handling and interaction with people during handling are both scientifically valid measures for assessing cattle welfare at slaughter plants. Falling is most likely to be caused by slippery floors. One

Table 11.3. Improvements in handling measurements after procedures were corrected.

	Cattle insensible on rail	Cattle electrically prodded	Cattle slipping	Cattle falling	Cattle vocalizing
NAMI (1) Pass percentage	100%	≤ 25.0%	≤ 3.0%	≤ 1.0%	≤ 5.0%
Before: N=29	100%	6.9%	3.4%	0%	10.3%
After: N=19	100%	0.0%	0.0%	0%	5.3%

of the problems is that flooring wears out slowly and people do not realize that the frequency of slipping and falling is increasing. This is why regular audit of slipping and falling is essential. Falling scoring is recommended by NAMI (2017), Welfare Quality (2009), OIE (2018) and Grandin (1998b). Boxes that are designed to make cattle fall should never be used. To facilitate shackling of fully conscious live animals, some boxes are mechanically designed to cause an animal to fall down. Use of this type of equipment would be an automatic failure of animal welfare audits. Boxes that are designed to restrain an animal by clamping its legs are also an automatic failed welfare audit.

Problems with restraint equipment

Problems with restraint equipment are outlined in [Box 11.1](#). Common engineering problems with restraint boxes are outlined in [Box 11.2](#).

Handling and restraint of poultry

Some plants that do either kosher or halal poultry without stunning hang the live birds on a conventional shackle line. This is allowed in all the countries and in the OIE (2018) guidelines. In small plants, each bird can be gently held by a person while the slaughterer makes the cut. After the cut, the bird is either hung on the slaughter line or placed inverted in a bleeding cone. Hanging live poultry on the shackle line is extremely stressful (Kannan *et al.*, 1987; Bedanova *et al.*, 2007). Restraining broiler chickens in cones is less stressful than shackling (Ismail *et al.*, 2016). Both halal and kosher plants have developed systems where a series of cones are attached to a conveyor.

Welfare Issues During the Neck Cut

Extensive research has been done to determine the effects of slaughter without stunning on pain and

stress during the neck cut. The three main issues associated with neck cutting in conscious cattle, sheep or goats for halal or kosher slaughter are as follows.

- Pain associated with the neck cut (Grandin, 1994; Gibson *et al.*, 2009a,b,c; Gregory *et al.*, 2012; Sabow *et al.*, 2016).
- Aspiration of blood into the respiratory tract while the animal may still be conscious (Gregory *et al.*, 2012).
- Time to lose consciousness after the cut. Loss of consciousness is not instantaneous after the cut (Grandin, 1980; Newhook and Blackmore, 1982; Blackmore, 1984; Gregory and Wotton, 1884a,b).

Painfulness of the cut

One of the biggest issues is defining what the animal is experiencing before it loses consciousness and the ability to feel pain. Grandin (1994), Levinger (1995) and Rosen (2004) maintained that when the super-sharp long kosher knife ([Fig. 11.9](#)) is used, there is little reaction to the neck cut. Waving a hand in front of a steer's face caused a bigger reaction than cutting with the special kosher knife (Grandin, 1994). These observations were made in a plant that had low-stress restraint. This made it possible to separate reactions to restraint from the reactions to the neck cut. Other researchers have provided evidence that the cut is painful. Gibson *et al.* (2009a,b) and Sabow *et al.* (2016) used EEG methods to determine if the cut was painful. Unfortunately, they did not use the special kosher knife. When halal slaughter is done without stunning, the only requirement is a sharp knife. For Jewish kosher slaughter, there are also length requirements (Levinger, 1995). The knife must be twice the width of the ventral aspect of the neck (Levinger, 1995). The blade must be smooth with no nick and a whetstone is required for sharpening.

In Gibson *et al.* (2009a,b), calves were slaughtered with a knife that had a 24.5 cm blade. The

Box 11.1. Fixing problems with restraint equipment for all species

- **Animals refuse to enter the restraint box** – The most common problem is that approaching animals can see people and activity through the headholder. A shield should be installed in front of the headholder to block the incoming animal's view (Fig. 11.1). Another problem is air blowing into the faces of approaching animals. For further information on refusal to enter, see Chapter 6.
- **Cattle vocalize in the box** – The first step is to determine which part of the restraining process is causing the vocalization. Observe carefully to determine which part of the box the vocalization is associated with. The main parts that can cause vocalization are:
 1. Tailgate slammed on the animal.
 2. Rear pusher gate applies excessive pressure (Figs 11.7 and 11.8).
 3. Headholder applies excessive pressure. Another cause of vocalization in cattle or struggling in all species is being clamped too long in the headholder. The neck cut should be performed immediately after the head is restrained.
 4. Body shifts during rotation may cause all species to struggle. A rotating box must have an adjustable side so that the animal's body is supported when it is rotated. An adjustable side is required for the market in Israel (IVSAH, 2017). Rotation should not cause struggling in any species.
 5. Sharp edges on equipment or the animal's skin is pinched.

Box 11.2. Common engineering problems with restraint boxes

- **Lack of cylinder mid-stroke position control of air cylinders on pneumatically (air-operated) systems** – In poorly designed systems, the amount of pressure applied to the animal is either none or applied at the maximum pressure setting. Well-designed pneumatic systems make it possible to have 'mid-stroke' position control of air cylinders. This enables the operator to stop movement of a headholder or pusher gate at an intermediate position (Grandin, 1992). This makes it possible for the operator to control the amount of pressure that is applied to the animal.
- **Lack of separate individually set pressure controls for different parts of the restraint box** – On both pneumatic and hydraulic systems, the headholder should be set at a much lighter pressure. Heavy vertical gates and the rotation system on a rotating box require high settings. These high settings are usually too high for the parts that directly press against the animal. In cattle vocalization, scoring is useful to locate problems with excessive pressure. Different parts of the box will require separate pressure regulators on pneumatic systems and pressure relief valves on hydraulic systems.
- **Jerky motion** of different parts of the restraint box may cause all species to struggle. Flow controls and other devices should be used to provide smooth steady motion.
- **Lack of throttling ability** – This is especially important for the headholder. The best controls work like a car's accelerator. The operator can easily speed up or slow down movement.

blade was sharpened on a mechanical grinder. Regenstein (2017) stated that using a mechanical grinder may have made the blade rough. There is also a possibility that the blade was too short. The first author has observed neck cutting with knives that were too short. Cuts with these knives caused intensive struggling in both cattle and sheep. Sabow *et al.* (2016) had no knife description for their study on goats. Bozzo *et al.* (2018) measured stress hormones in Charolais cattle that were kosher slaughtered in a rotating box and compared them with cattle from the same farm that were

stunned with a captive bolt. Plasma cortisol, dopamine and norepinephrine concentrations at exsanguination were higher in the kosher group. Similar results were found by Petty *et al.*, (1994).

Aspiration of blood in respiratory tract

Researchers have found that while the cattle were still conscious, blood was aspirated into the trachea (windpipe) (Gregory *et al.*, 2009). It is likely that blood entering the respiratory tract would cause distress.



Fig. 11.7. Injury to the tail caused by excessive pressure from a poorly designed rump pusher gate. Photo shows hide on. (Photo courtesy of Erika Voogd.)



Fig. 11.8. Bruised rump caused by a gate either slamming on the rump or sharp edges on a rump pusher gate. Often the hide will appear normal but there are severe bruises. (Photo courtesy of Erika Voogd.)



Fig. 11.9. Special long knives used for kosher slaughter. The use of a knife that is too short will cause gouging of the wound. It is the opinion of both authors that these are the only type of knife that should be used on adult cattle. (Photo courtesy of Erika Voogd.)

Time to Loss of Consciousness After the Neck Cut

Effective captive bolt or electrical stunning causes all species to become unconscious instantly (Daly *et al.*, 1988). When good technique is used during kosher slaughter with the special knife, the length of time it takes for the bovine to collapse and lose consciousness can be greatly shortened. **Table 11.5** shows the improvement in the time required to lose consciousness. In an upright position, the time is based on a loss of posture (LOP) or eye roll; and in the inverted position, until eye rollback. These are indicators that can be easily used in a slaughter plant to improve the procedure. Sometimes cattle or sheep can have prolonged onset of unconsciousness of over 60 s (Grandin, 1980; Blackmore, 1984; Gregory and Wotton, 1984a,b).

In the worst case, cattle remained conscious after being removed from the box and they walked around (Grandin, 1980). To achieve a shorter collapse time (LOP), the plant where these data were collected made the following changes in their procedure. The animal was held in an upright box in the restrained position with very light pressure applied to its body. The vocalization score averaged 4.5%. Within an average of 3.8 s after the head was restrained, the kosher cut was performed. This reduces stress, because cattle become stressed if they struggle and fight the headholder. After the cut, pressure from the rear pusher gate was immediately relieved. The headholder was loosened but it remained up to facilitate the flow of blood and observation of eye roll. It should be noted that this plant utilized a secondary cut of the carotid arteries, after shechita, to facilitate bleeding. If blood obstruction was

Table 11.4. Time to start of eye rollback in a rotating restraint box during kosher slaughter of 1810 cattle (data from: Erika Voogd (2010–2014); NAMI, 2019).

	Good technique	Poor technique baseline before good technique started
Average time	23 s	33 s
Standard Deviation	3.78 s	–
Maximum	38 s	120 s
Minimum	13 s	–
Per cent that collapsed within 30 s	94%	68%

Table 11.5. Improvement of halal cut efficiency after corrective actions, upright box.

	Cattle cut efficacy (collapse and eye roll within 30 s)	Cattle insensible when exiting box	Cattle insensible on rail
Grandin Pass Percent	≤ 95.0%	100%	100%
Before improvements: N=29	86.2%	100%	100%
After improvements: N=19	94.7%	100%	100%

observed, one or both arteries were severed again. The USA allows a secondary cut to facilitate bleeding (FSIS Directive 6900.2 Rev. 2); however, only one cut is permitted in Canada (Government of Canada, 2018; CFIA, 2019).

Gregory *et al.* (2010) had similar results. They assessed time to collapse in an upright restraint box. Immediately after the halal neck cut, pressure on the bovine's body was released. The average time to collapse was 20 s and 8% of the animals had collapse times of over 60 s. This may have prevented the problem reported by Verhoeven *et al.* (2016). They found that upright restraint increased the times required to lose consciousness. They performed upright restraint in a box designed for inversion. Loosening the headholder may have caused the head to slump down and occlude bleed out.

List of correction actions

- All the corrective actions listed [Box 11.1](#) above.
- Replaced the knives and all knives were sharpened weekly by a service.
- A knife sharpener was installed for the slaughter person to use.
- To prevent needless suffering, all plants should implement a time limit (30–40 s) and a stun procedure for religiously slaughtered animals that fail to lose consciousness.

Methods to reduce the time to loss of consciousness

Gibson *et al.* (2015) and Gregory *et al.* (2012) reported that cutting the neck of a bovine close to C1 (cervical 1) position facilitated faster collapse. A high neck cut close to the jaw (cervical 1 position) averaged 13.5 s to collapse and a lower neck cut averaged 19 s. Similar results were reported by Gregory *et al.* (2012). It is also important to have a calm animal entering the restraint box. In cattle, there are sometimes problems with false aneurysms

that impede the flow of blood (Gregory *et al.*, 2008). Seventy-one per cent of the cattle that failed to collapse within 75 s had a false aneurysm with swelling on the ends of carotid arteries (Gregory *et al.*, 2010). The use of a sharp knife may reduce this problem.

The first author observed that, during kosher slaughter of large veal calves, a quick knife stroke induced a faster collapse than a slow knife stroke (Grandin, 1994).

Sheep lose consciousness more quickly than cattle

Many studies have shown that sheep will collapse and lose consciousness more quickly than cattle. Observations of behaviour, such as loss of posture, and EEG studies have confirmed this result (Newhook and Blackmore, 1982; Blackmore, 1984; Daly *et al.*, 1988). On average, sheep will lose consciousness in 2–14 s (Newhook and Blackmore, 1982; Blackmore, 1984; Gregory and Wotton, 1984b) and cattle will lose it in 17–85 s (Blackmore *et al.*, 1983; Blackmore, 1984; Gregory and Wotton, 1984a). All the sheep and cattle in these experiments were fully conscious when their necks were cut. There are differences between the blood vessel anatomy in the neck of cattle and sheep. Cattle have an additional blood supply to the brain from vertebral arteries in the back of the neck (Baldwin and Bell, 1963a,b; Blackman *et al.*, 1986). When the neck cut is performed, the vessels in the back of the neck are not severed. In sheep, when a single horizontal cut is made across the neck, the entire blood supply to the brain is severed. DIAREL (2010) and Dalmau and Anil (2016) recommended that if an animal remains conscious for over 40 s, it should be immediately stunned with a captive bolt. In Canada, the CFIA Guidelines for ritual slaughter of food animals without pre-slaughter stunning have best-practice performance criteria for large bovines that state that if unconsciousness is

not achieved within 30–40 s post-cut they should be stunned.

Ensuring loss of consciousness in poultry

Whether religiously slaughtered poultry are stunned or not stunned, the neck cut is important to ensure that the birds remain unconscious and bleed effectively. Most of the neck cuts are performed by trained slaughterers. The use of a sharp knife or chalef (for kosher operations) is critical to ensure that the cut is effective. Both carotid arteries should be cut, close to the head. If the cut is too shallow, bleeding may be slow or incomplete and birds may regain consciousness prior to scalding and/or feather removal. Poor bleeding can be visualized after scalding and feather removal by observing the presence of red pygostyles (red tail) and blood pooling in the neck. The preferred indicators for assessing unconsciousness are loss of eye reflexes in response to touch and loss of muscle tone (floppy head). Muscle tone should not be used alone (EFSA, 2013c).

Determining the onset of loss of consciousness and brain death in mammals

In Chapters 13 and 14 methods to determine the onset of unconsciousness and brain death are discussed in detail. Terlouw *et al.* (2016) made a differentiation between definitely conscious and brain dead. There is a transition zone between these two conditions. Verhoeven *et al.* (2016) found that EEG testing indicted that a veal calf held in the inverted position may still be conscious for a few seconds after loss of response to the menace/threat test (waving a hand in front of the eye) and a nose pinch. Righting reflex and time to collapse could not be evaluated, because the calf was inverted in a rotating box. Before invasive dressing procedures are performed, the animal must be brain dead. The corneal reflex and eyelash reflex and all other reflexes in the head must be absent. The Animal Health and Welfare (AHAW) Panel of the European Food Safety Authority (EFSA) recommended that, prior to invasive dressing procedures, livestock must have absence of rhythmic breathing, dilated pupils and complete loss of muscle tone (EFSA, 2013a,b). If a righting reflex occurs after hoisting, the animal is conscious (Grandin, 1998b). See Chapter 13 and Damau and Anil (2016).

When to remove an animal from the restraint box

Regulations will vary in different countries. From a welfare standpoint, the animal should remain in the restraint box until it is unconscious. It will be unconscious and probably in the transition zone to brain death after collapse (LOP), loss of righting, eye rollback and loss of menace/threat reflex. Before invasive dressing procedures are started, bleed-out must be completed and multiple indicators must show that the animal is brain dead. Some countries have regulations that, after the cut, an animal cannot be removed from the restraint box until 20 s have elapsed for sheep and 30 s for cattle. Trees (2018) recommended monitoring compliance with this interval with closed circuit TV.

Stunning Method and Religious Slaughter

Religious texts require that the animal must be alive when the neck is cut (Benzertiha *et al.*, 2017; Fuseini *et al.*, 2017). There is much discussion about how to define being alive. Some religious authorities want the animal to be conscious and others will accept rendering it unconscious before the cut. A fully reversible electrical stun does not kill the animal, but it renders it unconscious. Effective captive bolt stunning will cause instant loss of consciousness and destroy part of the brain, but the heart will remain beating for several minutes (Vimini *et al.*, 1983). If being alive is defined by a beating heart, this would make captive bolt stunning acceptable. A survey conducted in the UK found that 53% of Islamic scholars and > 95% of halal consumers considered reversible stunning to be halal compliant. Sabow *et al.* (2017, 2019) have an excellent review of halal-compliant electrical stunning methods.

Many Muslim religious authorities will allow pre-slaughter stunning of livestock and poultry (Nakyinsige *et al.*, 2013; Fuseini *et al.*, 2017; Lambooi and Hindle, 2017). The preferred method is electrical stunning that is fully reversible and the animal or bird could completely recover (if exsanguination was not performed). Sabow *et al.* (2017, 2019) had an excellent review of all the fully reversible electrical stunning methods for livestock and poultry. Muslims want death to be induced by the neck cut and not by the stunning method. Within the Muslim community, there has been

much discussion (Fuseini *et al.*, 2016, 2017). When electrical stunning is used in halal cattle, sheep or poultry, it is designed to be fully reversible. It induces a period of unconsciousness that is sufficient to perform the neck cut. Head-only electrical stunning of sheep and calves will induce a period of unconsciousness for 18–42 s (Blackmore and Newhook, 1982). Velarde *et al.* (2000) found that sheep had a longer period of unconsciousness if the tongs were placed in a frontal position (between the eyes and ears on either side of the head) than in a caudal position (behind the ears on the occipital condyle on either side of the head). Research is also being conducted on novel reversible stunning with microwaves (Small *et al.*, 2019).

Reversible poultry stunning

Reversible electrical water-bath stunning methods for poultry are controversial because they often use lower amperages than in current European regulations. The first author has observed halal slaughter of chickens with fully reversible water-bath electrical stunning. To ensure that the birds did not recover, bleeding had to be done a few seconds after stunning. To prevent return to consciousness, signs of return to sensibility such as spontaneous natural blinking and loss of neck tension should be measured both before and after bleeding. EFSA (2014) reported that 104 mA, 126 volts at a frequency of 590 Hz was not effective in stunning poultry. Newer studies showed that a frequency of 750 Hz at 200 mA was effective for water-bath stunning of 88% of the broilers studied (Girasole *et al.*, 2015). Siquera *et al.* (2017) found that 650 Hz at 100 mA, AC was effective in 85% of the broilers studied. Allowing approximately 20% of the birds to be not effectively stunned would compromise the welfare of these birds. Girasole *et al.* (2015) conducted studies to determine the settings that would prevent return to sensibility in broiler chickens for 20 s. The electrical settings were 200 mA at 400 Hz and 250 mA at 400–600 Hz. The use of frequencies over 600 Hz is not recommended (Girasole *et al.*, 2015). Fuseini *et al.* (2018) discussed problems with conventional water-bath stunning from a halal perspective. They stated that a new head-only electrical stun system for broilers that uses tongs was effective in that eye reflexes were absent in 90% of the birds 90 s after stunning, but 95% recovered from the stun after 120 s (Fuseini *et al.*,

2018). One of their main concerns about electrical water-bath stunning was the bird dying before it was slaughtered.

Captive bolt and religious slaughter

Some Muslim religious authorities will accept pre-stunning with a captive bolt. It is allowed because the heart continues to beat for several minutes after both penetrating and non-penetrating captive bolt. If bleeding is delayed, the heart will beat for 8–10 min (Vimini *et al.*, 1983). A penetrating captive bolt is acceptable to some religious authorities but others will only accept a non-penetrating captive bolt. They would prefer that the skull not be fractured (Fuseini *et al.*, 2016). The author has observed that it is extremely difficult to avoid fracturing the skull and still render the animal unconscious. The basic concern is the fear of eating an animal that is dead before the neck cut (Fuseini *et al.*, 2016). The first author has also observed that a small dent is required to ensure instant unconsciousness. Oliveira *et al.* (2018) found that in large cattle a non-penetrating captive bolt was less effective for inducing loss of unconsciousness compared with a penetrating captive bolt. A study with bulls that recorded the EEG showed that a non-penetrating captive bolt was less effective than a penetrating captive bolt (Gibson *et al.*, 2019). In calves, a non-penetrating captive bolt was effective (Gibson *et al.*, 2009c; Bartz *et al.*, 2015). Muslim religious authorities are often more flexible about accepting stunning than Jewish rabbinical authorities. This may be partly due to Muslims having less reliance on centralized authorities. Decisions are more likely to be local. Orthodox glatt kosher slaughter never allows stunning. Less strict interpretation of Jewish law may accept an immediate post-cut stun. In the USA, it is common to have both types.

Labelling issues of non-stunned slaughtered meat

Another issue that abattoir managers must face is increasing requirements to label meat that originates from animals slaughtered without stunning. Alexander Trees, Editor of the *Veterinary Record*, stated that it should be labelled (Trees, 2018). Costain (2018) suggested a labelling system for identifying all types of both non-stunned and stunned slaughter. This would enable consumers to make choices about where their meat comes from.

These requirements will probably increase and this will require plant operation managers to keep stunned and non-stunned meat separated. The easiest way to accomplish this and to avoid mixing up carcasses is to have an entire day or days for non-stunned slaughter and other days for stunned.

Conclusions

Both authors, who have observed religious slaughter without stunning, consider that it can be done with an acceptable level of welfare, but careful attention to detail of the procedure is required. If procedures become sloppy, welfare will greatly deteriorate. Slaughter without stunning is more difficult to manage properly than conventional slaughter with stunning. Due to the attention to detail that is required for slaughter without stunning, serious welfare problems may be more likely to occur. Pre-slaughter stunning will improve welfare because it is easier to manage the process compared with slaughter without stunning.

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12 Auditing and Assessing the Welfare of Livestock and Poultry During Pre-slaughter Handling and Stunning

TEMPLE GRANDIN*

Department of Animal Science, Colorado State University, USA

Summary

Animal-based measures are an effective method for both auditing and monitoring handling and stunning of livestock and poultry in commercial abattoirs. The following variables should be measured. For livestock, the percentage of animals is assessed on five measures: (i) effective stunning with one application; (ii) insensible on the bleed rail; (iii) falling during handling; (iv) electric prod use; and (v) vocalization. For poultry, the percentage of birds is scored on six measures: (i) broken wings; (ii) broken legs; (iii) overloaded transport containers; (iv) broken transport containers; (v) effective stunning; and (vi) uncut red birds. Vocalization and electric prod use in cattle and pigs can be associated with higher physiological measures of stress. Legislative recommendations from the European Food Safety Authority (EFSA, 2013a–d) and OIE (2018) and legislative requirements from FSIS/USDA (2017) are outlined. Their similarities and differences are discussed. Written Standard Operating Procedures (SOPs) and corrective actions should comply with both legislative and customer requirements. SOPs should clearly state the specific operations in each abattoir and should not be copied from industry or government documents. Large abattoirs will need an animal welfare officer who has taken a training course that is approved in that country. Future welfare assessment methods such as gap analysis are explained.

Learning Objectives

- Learn how to use animal-based measures to assess stunning and handling.

- Explain the relationship between livestock vocalization and electric prod use with physiological measures of stress.
- Learn the similarities and differences between US, OIE and EU slaughter regulations.
- Explain how to write Standard Operating Procedures (SOPs).
- Introduce the duties of the animal welfare officer.

How to Maintain High Standards

Maintaining high standards of effective stunning and pre-slaughter handling requires constant supervision of all procedures. There is a difference between an effective welfare assessment system for practical everyday commercial use and more detailed assessments for scientific research. Effective systems for commercial use have to be simple and easy for people to learn, with a limited number of measurements (Grandin, 2010). They are designed to locate serious welfare issues that need immediate corrective action. Assessment tools designed for either research or more in-depth assessment of welfare can provide more detailed information (Wigham *et al.*, 2018).

The first section of this chapter will discuss the successful use of a simple numerical scoring system and the second half will discuss compliance with both FSIS/USDA and European Union (EU) regulations. The author has worked extensively with the creation and application of voluntary private industry standards that have been very effective for preventing serious welfare problems (Grandin 2000, 2001, 2010). In 1999, the use of an objective

* Email: cheryl.miller@colostate.edu

outcome-based numerical scoring system was first started in the USA. This occurred before the Humane Slaughter laws were strictly enforced by the Federal Government. Baseline data collected by Grandin (1998a) in federally inspected slaughter plants indicated that only 30% of the beef abattoirs could effectively stun 95% of the cattle with a single shot. The major cause of poor stunning was broken or poorly maintained captive bolts (Grandin, 1998a). At this time, the handling methods were very poor and some abattoirs used an electric prod on 100% of the animals (Grandin, 1998a). Today unpublished industry data indicate that 98–99% of the cattle are effectively stunned with a single shot.

In 1999, three major beef and pork buyers – McDonald’s Corporation, Wendy’s International and Burger King – started auditing their US federally inspected beef suppliers with simple objective numerical scoring. This resulted in huge improvements. The penalty for poor performance was removal from the approved supplier list. Out of 75 beef and pork plants on the McDonald’s supplier list, only three had to purchase expensive equipment or build a new lairage or races to comply with the new standard (Grandin, 2005). To dramatically improve animal welfare, they performed a whole series of small changes that added up to great improvements. **Box 12.1** gives a list of the most common modifications of handling procedures and equipment.

Simple Effective Assessment with Outcome-based Numerical Scoring

The scoring system was effective because it was simple to understand. It was like having easy-to-understand traffic laws for slaughter plants. Traffic laws are not vague. A stop sign means stop. Both speeding and alcohol levels in a driver’s blood are numerically measured. If the police only enforced these three items, they would probably achieve significant public safety improvements.

Commercial meat buyers and regulatory officials need simple easy-to-use assessments, which enable auditors to be trained in a one- or two-day workshop. They also need clear guidance on critical non-compliances that must be corrected. Some examples would be acts of abuse such as dragging conscious non-ambulatory animals, beating livestock or deliberately slamming gates on them. These abuses would be grounds for either removal from an approved list or regulatory penalties. Guidance must be clear on what is acceptable and what is not acceptable. This avoids lawsuits when suppliers have to be removed from a buyer’s approved supplier list.

Five Simple Numerically Scored Outcome-based Measurements for Assessing Livestock Stunning and Handling

An effective critical control point provides an assessment of multiple problems. It is based on directly

Box 12.1. Most common modifications of equipment and procedures to improve both animal welfare and numerical animal-based scores for livestock

- Stopped using electric goads (prods) as the primary driving tool. Handlers were not allowed to carry them constantly.
- Improved stunner maintenance – especially important for captive bolt.
- Non-slip flooring installed in stun boxes and unloading ramps.
- Reduced pushing pressure and installed manual controls on powered pusher gate systems used for moving pigs. This prevents the pigs from getting knocked over by the gates or being dragged.
- Training employees to move smaller groups of pigs and cattle from the lairage to the stunning area.
- Employees were taught behavioural principles of livestock handling, such as flight zone and point of balance (see Chapter 6).
- Changed lighting to remove reflections and added lamps to light up dark race entrances (see Chapter 6).
- Removed distractions that caused animals to baulk and refuse to move forward (see Chapter 6).
- Installed solid panels in strategic locations to prevent approaching animals from seeing people or moving conveyors up ahead of them.
- Reduced air hissing and metal clanging. A smart-phone app can be used to monitor noise levels (Lulietto *et al.*, 2018) and monitor progress on reducing noise.
- Stopped air blowing down a race towards approaching animals through the stun box door. Animals will often stop moving if air is blowing into their faces.

observable events that can be numerically scored. Numerical scoring is used in many different guidelines (Grandin, 1998a; Welfare Quality, 2009; NAMI, 2019; Australian Meat Process Corp., 2018; OIE, 2018). It is not a paperwork audit. For example, poor stunning could be due to either poor maintenance or an untrained operator. Cattle or pig vocalization in the stunning area could be due to electric prods, excessive pressure from a restraint device, or a sharp edge (Grandin, 1998a, 2001; Bourquet *et al.*, 2011). To pass the audit, the abattoir must have a passing score on all five variables.

1. Percentage of livestock rendered unconscious and insensible with a single application of the stunner (Grandin, 1998a, 2010; Welfare Quality, 2009). For captive bolt, it must be 96% to pass (NAMI, 2019). For electrically stunned animals, the tongs or other electrode application devices must be placed in the correct position on 99% of the livestock. The criterion is the same for both manual and automatic systems.

2. Percentage rendered unconscious before bleeding. Must be 100% to pass. The reason why the industry's voluntary standard allows a small percentage of second applications of the stunner is to help prevent hanging fully conscious animals on the rail. Stunner operators are encouraged to take an occasional second shot when necessary. When they try to be perfect, it increases the risk of hanging a conscious animal on the rail. If any sign of either consciousness or brainstem reflexes occurs during carcass processing (invasive dressing procedure) the audit is automatically failed.

3. Percentage of livestock moved with an electric prod (goad) (Grandin, 1998a, 2010; Simon *et al.*, 2016; Woiwode *et al.*, 2016). For an excellent score, an electric goad would be used on 5% or less of the cattle or pigs. In sheep and neonatal calves, electric prod use should be avoided (OIE, 2018). Use for both conventional and non-stunned religious slaughter.

4. Percentage of animals that fall during handling at any place in the abattoir from the unloading ramp to the stun box (Grandin, 1998a, 2010; Welfare Quality, 2009; Messori *et al.*, 2016; Losada-Espinoza *et al.*, 2017; OIE, 2018). Stun boxes that have floors which cause animals to fall would result in an automatic failed audit. Falls must be 1% or less of the animals. All falls caused

by powered gates are counted. Use for both conventional and non-stun religious slaughter.

5. Percentage of cattle or pigs vocalizing in the stunning area (Grandin, 1998a, 2001; Welfare Quality, 2009; Losada-Espinoza *et al.*, 2017) – bellowing or mooing in cattle, and pigs squealing. Each animal is scored as either silent or as a vocalizer. To make vocalization practical, it is much easier to score each animal as silent or vocalizing during stunning and handling. In cattle, all vocalizing animals in the stun box or non-stun religious slaughter box are counted. Cattle that vocalize in direct response to electric prods while entering the box are also counted. To pass, the percentage of cattle that vocalize must be 3% or less. If a headholder is used, then the acceptable percentage of vocalizing cattle is 5%. Use for both conventional and non-stun religious slaughter. Do not use vocalization scoring for sheep. For pigs, it is difficult to determine which pig in a group of pigs is squealing. If pigs are stunned on the floor with electric tongs, score each pig as silent or squealing when it is handled for stunning. If the pigs are held in a restrainer, score each pig as silent or squealing. For all species, never score vocalization in the lairage for the basic audit, because animals may vocalize for reasons unrelated to handling or restraint. The purpose of vocalization scoring is to identify severe problems with stressful handling or poor restraint. It can identify serious welfare issues with either restraint equipment or excessive electric goad use. For example, reducing pressure from a head restraint device reduced the percentage of cattle vocalizing from 23% to 0% (Grandin, 2001).

Clever Traffic Light Pig Squeal Meter

To help motivate a programme for continuous improvement in handling, some progressive managers have installed sound decibel meters in the room where the pig stunner is located. This will work with all types of stunners. The decibel meter is wired to a traffic light. The light is green when the squealing level is low and it turns red when the squeals increase. This is an excellent method for assessment within an abattoir. It will not work between plants, because each plant has a different number of pigs in the room. For all species, never score vocalization in the lairage. The purpose of vocalization scoring is to locate problems with either excessive electric goad use or problems with restraint equipment.

Most Common Modifications to Equipment and Procedures to Improve Animal Welfare and Numerical Scores for Poultry

- Improve maintenance of transport containers to prevent injuries to the birds.
- Use incentive pay for catchers to reduce broken wings and death losses.
- Limit catching shifts to 6 h. When workers get tired, bird injury increases.
- Eliminate people walking under the shackled birds or other disturbances at the entrance to the electric stunner.
- Sort out undersized birds that are too short to be properly stunned in an electric stunner.
- Install either a video camera or windows in controlled atmosphere stunners for constant monitoring of behaviour before loss of posture. Bird welfare has been seriously compromised if the birds attempt to escape from the container before loss of posture and losing consciousness (see Chapters 13, 14). If this occurs, the protocols for anaesthesia must be corrected.

Nine Simple Outcome Measures for Assessing Poultry Catching, Transport, Handling and Stunning

1. Percentage of birds with broken or dislocated wings. Score with the feathers on, to avoid confusion with defeathering machine damage. The percentage of birds with broken wings should be under 1% (Welfare Quality, 2009; Grandin, 2017; Jacobs *et al.*, 2017).
2. Percentage of birds with a broken leg.
3. Percentage of overloaded transport containers. All birds should be able to lie down without being on top of each other. A container is defined as: (i) a single coop; (ii) a single drawer; or (iii) a single compartment in a dumping module. Limit 1% overstocked. Although overstocking is a major source of heat stress, understocking during cold weather can increase cold stress (Cockram *et al.*, 2018). Each facility should determine clear cold-weather stocking densities.
4. Percentage of broken transport containers. A container is scored as broken if a plastic slat is missing or a piece of wire has broken loose. Limit 1% of the containers are broken.
5. Percentage of birds with body parts stuck in drawers or doors of transport containers (Vissar *et al.*, 2014).

6. Percentage of birds that miss the electric stunner. Must be 99% or more correctly stunned.
7. Uncut red birds in electric stunning systems. Red birds occur when a bird fails to bleed out. After feather removal, it will be bright red because it did not bleed. A red bird that does not have its throat cut from either the cutting machine or the back-up bleeder person may have entered the scalding alive. A single uncut red bird is a failed audit.
8. Percentage of birds that are dead on arrival (Weeks *et al.*, 2019).
9. Percentage of bruised birds. Count a bird as bruised if it has bruises larger than 19 mm (0.75 in) (Jacobs *et al.*, 2017).

Acts of Abuse are Automatic Failed Audit

An audit is failed if any of the abuses listed in Chapter 2 are observed. Some examples are beating animals, dragging conscious non-ambulatory animals or poking sensitive areas such as the eyes, mouth or anus.

Effectiveness of Animal-based Measures

A review of the literature on pre-slaughter handling validated assessment of cattle welfare during handling by scoring: (i) interactions with handlers such as electric prod use; (ii) falling; and (iii) vocalization (Losada-Espinosa *et al.*, 2017). These three measures can be easily conducted in a commercial slaughter plant. Previous research has clearly shown that procedures improve when stunning and handling are assessed with numerical scoring (Grandin, 2000, 2001, 2012). This is especially true when large meat-buying customers are insisting on high standards.

In poultry, scientific studies have validated scoring of bruises and broken wings (Kittelsen *et al.*, 2015; Jacobs *et al.*, 2017). Extensive data has also been published on the incidence of bruises and dead on arrival (Langkebel *et al.*, 2015; Caffrey *et al.*, 2017; Jacobs *et al.*, 2017). The other measures were developed by the author for use by large buyers of poultry (www.grandin.com). A recent problem in the poultry industry is that there are large amounts of commercial research on stunning and handling that are never published. The acceptable cut-off points for some of the variables were determined from unpublished information obtained during commercial audits.

A High Percentage of Animals Vocalizing and Electric Prod Use Is Related to Physiological Measures of Stress

In both cattle and pigs, vocalizations during handling and restraint are related to physiological measures of stress. In cattle, vocalization during restraint and handling is associated with higher cortisol levels (Dunn, 1990; Hemsworth *et al.*, 2011). In pigs, vocalization during handling was associated with poorer meat quality (Warriss *et al.*, 1994; Hambrecht *et al.*, 2004, 2005; Edwards *et al.*, 2010a,b).

Electric prod use is very detrimental to pigs (Benjamin *et al.*, 2001). When it occurs shortly before stunning, lactate levels increase and meat quality is lower (Faucitano, 1998, 2010; Hambrecht *et al.*, 2004, 2005; Correa *et al.*, 2010). In cattle, multiple shocks with an electric prod shortly before stunning resulted in tougher beef (Warner *et al.*, 2007). Gruber *et al.* (2010) reported that behavioural agitation in the stunning race resulted in higher lactate levels at bleeding. Dokmanovic and Baltic (2014) reported that pig squealing and electric prod use were associated with higher lactate levels in the blood. Vocalization scoring of pigs during pre-slaughter handling is a promising indicator (Brandt and Aaslyng, 2015).

Reducing Electric Prod Usage and Modifying Restraint Devices Reduces Vocalization

Grandin (1998b, 2001) reported that cattle vocalizations were directly associated with obvious aversive events such as electric prod use, excessive pressure from a restraint device or missed captive bolt stuns. In two abattoirs, when electric prod use was greatly reduced, the percentage of cattle that vocalized dropped from 32% to 12% in one plant and 12% to 3% in the second plant (Grandin, 1998b). In one survey, 86% of the cattle abattoirs had a vocalization score of 2% or less (Grandin, 2000). Simple improvements can greatly reduce the percentage of cattle that vocalize during handling and restraint. Reducing pressure applied by a headholder reduced the percentage of cattle vocalizing from 23% to 0% (Grandin, 2001). Bourquet *et al.* (2011) also reported that a high 25% vocalization score was due to excessive pressure from a restraint device. A plant that had almost 100% of the cattle moved with electric prods had 47% of cattle vocalizing (Hayes *et al.*, 2015). Simple changes to improve

cattle movement, such as adding a light to a restrainer entrance, reduced vocalization due to electric prod use from 8% to 0% (Grandin, 2001).

In five abattoirs, modifications discussed previously were made to equipment. Before modification, 12.8% of the cattle vocalized; after modification, the percentage of cattle vocalizing dropped to 1% (Grandin, 2001).

How Stressful is Slaughter of Livestock?

An animal welfare officer at a slaughter plant may be asked, 'Do animals know they are going to be slaughtered?' The author has observed that animal behaviour during handling is similar in both the farm and in the slaughter plant. If animals knew they were going to be slaughtered, there should be greater agitation at the abattoir. Evaluation of physiological measures of stress indicated that levels of lactate, glucose or cortisol were similar to levels after on-farm cattle handling. Lactate and glucose respond very quickly to an aversive event such as an electric prod. Lactate and glucose measures could be used as an easy way to monitor handling quality of pigs at slaughter (Edwards *et al.*, 2010b). Meters for measuring lactate and glucose are easy to use and economical. Cortisol requires 15–20 min to reach peak levels (Lay *et al.*, 1992, 1998). Indicators such as adrenaline (epinephrine) and noradrenaline cannot be used, because stunning causes massive release (Warrington, 1974; Pearson *et al.*, 1977; Van der Wall, 1978). When electrical stunning or captive bolt stunning is done correctly, this massive release of stress hormones has no effect on welfare. The animal is rendered instantly unconscious and is not aware of the hormone release.

In some studies, cortisol levels are expressed in nanomoles per millilitre (nmol/ml) by multiplication of ng/ml by 0.36. Tame animals that are trained to lead often have baseline cortisol levels when they are handled for veterinary procedures. When brought to a slaughter plant, tame draught animals often show little or no behavioural signs of agitation.

Slaughter cortisol levels in cattle

When slaughtering is carried out carefully, cortisol levels in cattle can be substantially lower compared with on-farm handling of extensively raised cattle. Tume and Shaw (1992) reported that steers and heifers slaughtered in a small research abattoir had

average cortisol levels of only 15 ng/ml and cattle slaughtered in a commercial slaughter plant had levels similar to those of on-farm handling of extensively raised cattle. Bison shot in the field had very low cortisol levels of 6.48 ng/ml and bison shot in a commercial plant had 36 ng/ml (Duane Lammers, 2012, personal communication).

For commercial slaughter of extensively raised cattle with captive bolt stunning, the following average cortisol values have been recorded: 45 ng/ml (Dunn, 1990), 25–42 ng/ml (Mitchell *et al.*, 1988), 44.28 ng/ml (Tume and Shaw, 1992), 24 ng/ml (Ewbank *et al.*, 1992), 66 ng/ml in two large export abattoirs (Hemsworth *et al.*, 2011). The high cortisol levels in Hemsworth *et al.* (2011) may have been due to extensively raised Brahman-cross cattle from the Australian outback. A French study with intensively raised young fed bulls had cortisol levels of 21 ng/ml at slaughter (Mounier *et al.*, 2006). Bulls often have lower cortisol levels compared with steers. Gentle stroking of newborn calves for 10 min on five different days lowered cortisol levels at slaughter from 49 ng/ml to 29 ng/ml (Probst *et al.*, 2012). When things go wrong, the stress levels increase greatly. Cockram and Corley (1991) reported a median value of 63 ng/ml. One animal had a high of 162 ng/ml. This was probably due to constant slipping on the floor.

Cortisol levels similar to on-farm handling

Cortisol levels during handling at a slaughter plant are similar to on-farm handling and restraint for blood testing (Grandin, 1997, 2014). Baseline cortisol levels in cattle at rest can vary from a low of 2 ng/ml (Alam and Dobson, 1986) up to 9 ng/ml (Mitchell *et al.*, 1988). In another study, beef cattle on a research station that had become accustomed to being handled for different experiments had cortisol levels that ranged from 10 ng/ml in calm animals to 15 ng/ml in the more excitable individuals (King *et al.*, 2006). Restraining extensively raised semi-wild cattle for blood testing under farm conditions elicited cortisol readings of 25–33 ng/ml in steers (Zavy *et al.*, 1992), 63 ng/ml in steers and cows (Mitchell *et al.*, 1988), 27 ng/ml in steers, 63 ng/ml in steers and cows (Mitchell *et al.*, 1988), 27 ng/ml in steers, 24–46 ng/ml in weaner calves (Crookshank *et al.*, 1979) and 41 ng/ml in British/Continental beef breed (*B. taurus*) steers handled in the early morning (Vogel, 2011). Furthermore, cortisol has diurnal variations and may be higher earlier

in the day (Gygax *et al.*, 2006; Hemsworth *et al.*, 2011). In Braham and Brahman-cross cattle, cortisol values ranged from 30 to 35 ng/ml after 20 min restraint in a squeeze chute (Lay *et al.*, 1992, 1998); the levels were 12 ng/ml after 5 min and rose to 23 ng/ml after 10.5 min of restraint (Lay *et al.*, 1998).

Detrimental effects of poor handling of cattle

The slaughter plant observed by Cockram and Corley (1991) had a poorly designed forcing pen and slippery floors. About 38% of the cattle slipped after exiting the holding pens and 28% slipped just before entering the race. Cortisol levels also increased when delays increased waiting time in the single file race. This was the only study where vocalizations shortly before stunning were not correlated with cortisol levels. This can probably be partly explained by earlier stress caused by the slippery floors. Cortisol levels were lower and stress was reduced when cattle were transported and slaughtered with their penmates (Mounier *et al.*, 2006).

Ewbank *et al.* (1992) found a high correlation between cortisol levels and handling problems in the stun box. Use of a poorly designed head restraint device, which greatly increased behavioural agitation and the time required to restrain the animal, resulted in cortisol levels jumping from 24 to 51 ng/ml. In the worst animal, the level increased to 96 ng/ml. Cattle slaughtered in a badly designed restraining pen that turned them upside down had average values of 93 ng/ml (Dunn, 1990). Very few sexually mature bulls have been studied, though Cockram and Corley (1991) had a few in their study. Sexually mature bulls have much lower cortisol levels than steers, cows or heifers (Tennessen *et al.*, 1984).

Cortisol levels and stress in sheep and goats

Sheep research also shows that cortisol levels at an abattoir are similar to those in on-farm handling. Slaughter in a quiet research abattoir resulted in much lower average levels (40 ng/ml) compared with a large noisy commercial plant that had dogs (61 ng/ml) (Pearson *et al.*, 1977). In two large sheep export abattoirs in Australia, the mean cortisol level was 67 ng/ml (Hemsworth *et al.*, 2011). In a Brazilian abattoir, cortisol levels were 24 ng/ml after 3 h in large. Preventing sheep from seeing outside the truck during transport reduced cortisol at unloading from 35.49 ng/ml to 29 ng/ml (da Cunha

Leme *et al.*, 2012). Shearing and other on-farm handling procedures provoked similar or slightly greater stress levels of 73 ng/ml (Hargreaves and Hutson, 1990), 72 ng/ml (Kilgour and de Langen, 1970) and 60 ng/ml (Fulkerson and Jamieson, 1982). Restraint and isolation stress for 90–120 min increased cortisol levels to 80–100 ng/ml in sheep (Apple *et al.*, 1993; Rivalland *et al.*, 2007). Baseline levels were 22 ng/ml. Extremely high cortisol levels of 119 ng/ml were obtained in a slaughter plant where each sheep was individually picked up by a person to unload the trucks (Ekiz *et al.*, 2012). Five min of exposure to barking dogs increased cortisol levels in kids (Zimmerman *et al.*, 2012).

Do Blood Odours Upset Livestock?

Many people interested in the welfare of livestock are concerned about animals seeing or smelling blood. Cattle will baulk and sniff spots of blood on the floor (Grandin, 1980a,b), and washing the blood off facilitates movement. The baulking may be a reaction to novelty, as a piece of paper thrown in the race or stunning box elicits a similar response. Cattle will baulk and sometimes refuse to enter a stun box or restrainer if the ventilation system blows blood smells into their faces at the stun box entrance. They will enter more easily if an exhaust fan is used to create a localized zone of negative air pressure. This will suck smells away from cattle as they approach the stun box entrance. Application of mentholated ointment to a horse's nostrils may help to reduce stress at slaughter. Micera *et al.* (2012) reported that the ointment reduced adrenaline and noradrenaline levels.

Observations in Jewish religious (kosher) slaughter plants indicate that cattle will readily walk into a restraining box that is covered with blood. In kosher slaughter, the throat of a fully conscious animal is cut with a razor-sharp knife. Cattle will calmly place their heads into the head restraint device and some animals will lick blood or drink it. Pigs will eat or root in blood when they are slaughtered in groups (Schaeperkoetter *et al.*, 2019). Kosher slaughter can proceed very calmly with few signs of behavioural agitation if the restraining box is operated gently (Grandin, 1992, 1994). Research by Schaeperkoetter *et al.* (2019) indicated that watching other pigs being stunned and bled did not raise blood lactate levels.

However, if an animal becomes very agitated and frenzied during restraint, subsequent animals often

become agitated and an entire slaughter day can turn into a continuous chain reaction of excited animals. The next day, after the equipment has been washed, the animals will be calm. The excited animals may be smelling an alarm pheromone from the blood of severely stressed cattle. Blood from relatively low-stressed cattle may have little effect, but blood from severely stressed animals that have shown signs of behavioural agitation for several minutes may elicit a fear response. Eible-Eibesefeldt (1970) observed that if a rat is killed instantly in a trap, the trap can be used again, but the trap will be ineffective if it injured the rat and failed to kill it instantly.

Research with pigs and cattle indicates that there are stress pheromones in saliva and urine. Vieuille-Thomas and Signoret (1992) and Boissy *et al.* (1998) reported that pigs and cattle tended to avoid places or objects sprayed with urine from a stressed animal. The stressor must be applied for 15–20 min to induce the effect. In the cattle experiment, the animals were given repeated shocks for 15 min (Grandin, 2014).

Complying with Government Legislation and Regulations

Abattoir managers need to comply with two sets of requirements. They are the specifications and private standards from customers and compliance with government regulations. In this section, the first part will cover US regulations (FSIS, no date, 2013, 2016, 2017) and the second part will cover recommendations for EU regulations (EFSA, 2013 a–d). Abattoirs that specialize in export often have to comply with both the US and EU requirements. One of the problems with regulations is that some of them are often vague. In FSIS regulations, the livestock have to be moved with ‘minimum of excitement and discomfort’ (Regulation 9CFR313). Determining excessive use of electric prods is based on the opinion of the inspector. In the EU, the term ‘avoidable suffering’ is used in many documents (Council of European Union, 1979). Vague wording results in variation in how the regulations are interpreted and enforced.

US Regulations

Increased enforcement of existing legislation

In the USA, recent lawsuits and other actions by animal activist groups have motivated the Food

Safety Inspection Service (FSIS) of the US Department of Agriculture (USDA) to strictly enforce Humane Slaughter Act regulations. The inspectors have the power to suspend federal meat inspection and shut an abattoir down until problems are corrected. The length of the shutdown ranges from a few hours to several days for serious violations. In the USA, the Humane Slaughter Act does not cover poultry. As discussed in Chapter 11, it also has an exemption for religious slaughter. Missed captive bolt or gunshots are the primary area of enforcement by FSIS. The US law basically states that stunning must be perfect. To avoid shutdowns, many US abattoirs that were previously using electrical stunning for pigs have switched to CO₂. The use of CO₂ machines with long dwell times in the gas almost eliminates pigs returning to consciousness after they exit the machine.

The FSIS inspectors are most likely to enforce the Humane Slaughter Act regulations that are clearly worded. The regulations that have vague wording are less likely to be enforced. The areas that are most critical for managers to supervise are as follows.

- **Stunning efficacy.** Since it is impossible to be perfect, there is some leeway if a plant has a robust systematic approach. There will be further explanations of this later in this chapter. The actual wording is ‘all animals are rendered insensible to pain by a single blow or gunshot’ (FSIS/USDA Humane Slaughter of Livestock Regulation 9 CFR 213).
- **Provide water for all the livestock in the lairage.** This is worded very clearly.
- **Never drag non-ambulatory, conscious, downed animals.** ‘Stunned animals may be dragged.’ Be really careful with power pusher gates to avoid dragging pigs. Dragging animals with gates can result in a violation.
- **No pointed objects for driving livestock.** The wording is those that ‘in the opinion of the inspector would cause injury or unnecessary pain’. This wording has given the inspectors some flexibility.
- **Never start invasive dressing procedures on animals showing any eye reflexes.** Both FSIS and EU regulations require that animals are brain dead before carcass processing (invasive dressing procedure; also see Chapters 13 and 14).

Developing a robust systematic approach

People who manage both large and small US federally inspected meat plants need guidance that is simple and easy to understand. Some of the directives and

documents from the FSIS are hard for managers and quality assurance employees to understand. A major issue was finding an easy-to-understand definition of a robust systematic approach for humane slaughter compliance.

I had the opportunity to talk to Patty Bennett, DVM, when she was the Humane Handling Enforcement Officer for FSIS. We were on a conference call during the 2017 North American Meat Institute’s Animal Welfare Committee Meeting. I asked her to give me the definition of a robust systematic approach in plain, simple language that a plant manager could easily understand. After our discussion, the definition could be summarized to six major points. The first three points are clearly outlined in the document ‘FSIS Compliance Guide for a Systematic Approach to the Human Handling of Livestock’, which can be easily found on the internet. She outlined the first three points in plain easy-to-understand language:

- 1. Written procedures are required** for a robust systematic approach. Written standard operating procedures (SOPs) must describe both the procedures in your plant and the corrective actions that will be taken if there is a failure of a procedure.
- 2. Written records are required.** These records would contain the written procedures. They would also contain corrective actions and plant internal audits.
- 3. FSIS review.** Records would be shared with the FSIS meat inspectors upon request.

The above three items are ‘straight from the book’ (FSIS, 2013). The next three items are paraphrased from notes from my conversation with Dr Bennett:

- 1. The written program must match actual operations in the plant.** My interpretation of this is that the system is not robust if plant operations are different than the written document.
- 2. Does it work?** There is need for constant monitoring to determine if the programme is working. Numerical scoring is a good method to determine if procedures are either improving or becoming worse. My interpretation is that both the internal monitoring methods and records of corrective actions for problems must be included in the written records. This would allow someone who is reviewing the records to determine if procedures are improving or becoming worse.
- 3. Provide definite ways to fix problems.** This is especially relevant if there are re-occurring problems. Explains how problems were fixed.

Dr Bennett made it clear that a plant can have a robust systematic approach even if it is under an enforcement action.

FSIS/USDA HATS categories

The FSIS also has a system called HATS categories (FSIS, 2013). When an inspector sees a problem, they will write it up under a Humane Activity Tracing System (HATS) category. Below is a simplified list of HATS categories based on CFR 312.2 (FSIS, 2016).

1. Inclement weather – Includes both hot and cold weather. This section will include problems with slipping and falling on ice or frozen water troughs. During hot weather, lack of shade. Disabled livestock should be in a covered pen.
2. Truck unloading – This section includes slipping and falling, or forcing animals to move faster than a walking speed. Some inspectors will use numerical scoring to evaluate slipping, falling or excessive electric prod (goad) use.
3. Water/feed available – Water must always be available in lairage pens. Feed required after 24 h of holding in the lairage.
4. Ante-mortem inspection – Along with ante-mortem inspection for food safety, the inspectors will also observe handling. Major areas are excessive electric prod use and injuries due to handling practices.
5. Suspect and disabled animals – Never drag a conscious animal. Separate disabled animals from other animals.
6. Electric prod/alternative object use – No sharp objects. Does use of electric or other driving aids result in ‘over excitement or injury’? Some inspectors will use numerical scoring of falls, vocalization and percentage electric prodded to determine if handling practices are acceptable.
7. Slips and falls – Can be due to either slick flooring or poor handling. Some inspectors will use numerical scoring on falling and electric prod use.
8. Stunning effectiveness (Regulation 9CFR 313.5, 313.15, 313.16 313.30) – A robust systematic approach may help avoid a plant shut-down if a stun is missed. Requires records of CO₂ concentrations.
9. No conscious animals hung on the bleed rail (Regulation 9 CFR 313.5, 313.15, 313.16, 313.30) – See Chapters 13 and 14 on determining insensibility.

European Council (EC) Regulations

There is an excellent discussion on European regulations by Pinellos (2016). Both the European Union and the OIE recognize the importance of promoting global animal welfare standards. Some of the wording that is used in the regulation is vague, such as preventing ‘avoidable pain’. Below is a summary of the requirements for operators of slaughter plants. It has been summarized from Pinellos (2016).

1. Develop sampling practices to check efficacy of practices in your abattoir. Numerical scoring could be used for this.
2. Write SOPs for handling, restraining and stunning.
3. Maintain and keep clean all equipment used for handling, such as unloading ramps, waterers and pens. Keep maintenance records.
4. Always have a back-up stunner available.
5. Do not overstock lairage pens. Develop charts for number of animals that can be put in each pen. The author recommends that all the animals must be able to lie down without being on top of each other (Figs 12.1a, b and 12.2 could be used as part of an SOP on stocking density of the lairage).
6. Prompt unloading.
7. Good lairage conditions. Follow requirements for feeding and watering.
8. An Animal Welfare Officer is *required* for large abattoirs.
9. Monitor stunning. The author suggests that numerical scoring could be used for this purpose. Have documented maintenance procedures. The EU Regulation (Council Regulation (EC) No. 1099/2009) (European Council, 2009) requires SOPs that define parameters to indicate the effectiveness of stunning and the measures to be taken when checks indicate that an animal is not properly stunned. This wording would allow a few second applications to be legal.
10. Use equipment that complies with regulations.
11. Only accept the type of animals for which the slaughterhouse is officially approved.
12. Training of employees handling animals is essential. There should be documentation of the training materials that were used.
13. Manager must state maximum numbers, species and weight of animals that can be slaughtered per hour.

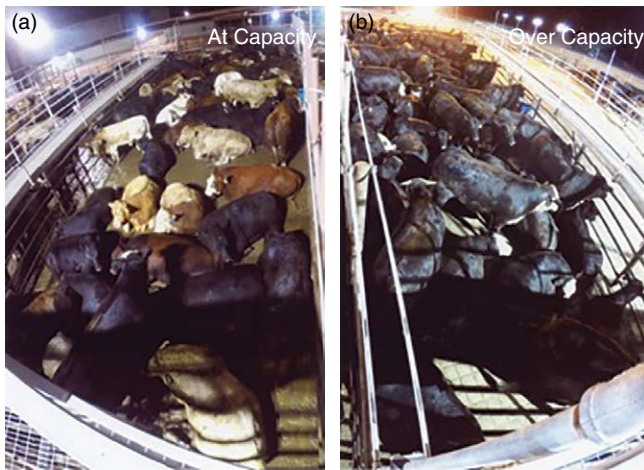


Fig. 12.1. (a) Correctly stocked pen and all the cattle can lie down and rest at the same time. (b) Overstocked cattle pen. The cattle are not able to all lie down and rest at the same time. (Photos courtesy of Helen Kline.)



Fig. 12.2. Lairage pen that is properly stocked with pigs. All the pigs have room to lie down without being on top of each other. A little extra space enables the pigs to get to the waterers. (Photo courtesy of Temple Grandin.)

Requirements for EU Animal Welfare Officers

The Animal Welfare Officer must directly report to the slaughter plant manager. To comply with EU regulations, a welfare officer is required for abattoirs that annually slaughter 1000 adult cattle or 5000 market-weight pigs. Poultry slaughter plants that process over 150,000 birds annually require a welfare officer. The duties of this person must be written as part of the abattoir's SOPs. There are two requirements for the animal welfare officer.

1. They must hold a certificate of competence for each of the operations for which they are responsible (European Commission, 2009). These are issued after completion of recognized training courses.

2. They must keep records of all actions for a year. The welfare officer should be involved in both implementation and development of SOPs and corrective actions.

The welfare officer has to have a programme for monitoring handling, stunning and condition of arriving animals. The author recommends numerical scoring of handling and stunning. See Chapter 4 on the condition of animals entering the abattoir. Some severely debilitated animals should never have been transported to the abattoir. They should have been euthanized on the farm. All employees who are handling, stunning or bleeding animals must have a training certificate. Use training courses that are approved in your country. There are often

several different choices. There is an excellent webpage titled The Animal Welfare Officer in the European Union (European Union, 2012). Other sources of training materials are: NAMI (2019), Humane Slaughter Association (HSA, 2019), OIE slaughter guidelines (OIE, 2018) and www.Grandin.com.

Similarities Between OIE, EU and US Procedures for SOPs

Many of the requirements are similar for both the FSIS Robust Systematic Approvals and EU requirements for SOPs. Write SOPs in simple language describing what you do in your abattoir. Do not copy standards from other slaughter plants or quote verbatim from industry guidelines. Do not write a book. [Box 12.2](#) gives an outline of a sample of SOPs.

Three Parts of an Effective Assessment System

A camera tripod has three legs. If one of the legs is missing, it will tip over. In a commercial assessment system, a third-party independent auditor will visit every facility. The second leg on the tripod is internal audits and assessments conducted by the animal welfare officer or other person designated by the plant management. The third leg is corporate buyer check audits. A management person from the buyer visits a sampling of abattoirs to ensure that the third-party auditors are doing their jobs.

In government regulatory systems, there are also three legs on the tripod. They are: (i) the government inspector assigned to the slaughter plant; (ii) the animal welfare officer at the plant; and (iii) the government inspector's supervisor. Both private standards and government systems have guidelines for the number of animals that should be sampled.

Remote Video Auditing

Video auditing using numerical scoring is being used in many abattoirs in the USA and closed-circuit TV is now required in the UK and Denmark. Auditors in a central control centre run by a private company randomly sample a group of animals in the stunning area, handling races, bleed rail and truck unloading area. If an auditor sees a non-compliance, the abattoir manager receives an email. Video auditing prevents the problem of people 'acting good' when they see a person with a clipboard.

Avoid Turning Compliance into a Paperwork Audit

Too many assessments have turned into paperwork audits, and observations of stunning and handling may be lacking. The paperwork may be in good order, but stunning and animal handling are terrible. Paperwork is important, but direct observation is most important. For EU, FSIS and private industry standards, records on training of people and maintenance of stunners and other equipment are important. Records also need to be kept of all non-compliances and corrective actions. Inspectors, animal welfare officers and auditors must get out in the lairage and stunning area and determine if the records accurately describe actual practices.

Training Materials

There are many sources of training materials for abattoir employees. In most countries, there are training materials that are readily available. Some good sources are NAMI (2019), Humane Slaughter Association in the UK, and OIE training materials. A particular buyer may have specific training materials and guidelines that should be used. The biggest problem the author has observed with training materials is failure to translate them into the languages used by the employees. Another approach is to use pictorial publications and videos where translation is not needed. A green check marker would show correct procedures and a red circle with a diagonal slash would show the wrong procedures.

Other Assessment Systems, ISO and Gap Analysis

There has been much discussion about assessing animal welfare with risk analysis, gap analysis or ISO. Some of this information has become really complicated. Below is a simplified explanation.

The International Organization for Standardization (ISO, 2016) has published an introductory document based on the World Organisation for Animal Health (OIE) published welfare standards for slaughter transport and production of beef cattle, dairy cattle and broiler chickens. This document is a guide for developing an animal welfare plan. The main guidance document is Chapter 7.1 Article 7.1.4 of the OIE Terrestrial Animal Health Code. This contains 11 General Principles of Animal Welfare. Fortunately, the document encourages the use of animal-based

Box 12.2. Outline of sample standard operating procedures (SOPs)

Write a few sentences for each item.

- Name of person who wrote the SOP
- Date written
- Name of supervisor

Description of Each Procedure – For example: (i) captive bolt stunning; (ii) unloading trucks; or (iii) handling non-ambulatory animals. Describe the procedures in your plant and write a separate SOP for each procedure.

Monitoring the Procedure – Some examples would be maintenance records for stunners or numerical scoring of handling and stunning. The frequencies of the observations and monitoring should be stated.

Corrective Actions – Describe procedures used to correct problems. Examples would be to re-train the employees or stop hiring a truck driver who dragged a downed animal. Acts of abuse should never be tolerated. It is recommended to state in very clear language the specific animal abuses that could result in termination of employment. These rules should be posted on signs in animal handling areas. If either a government meat inspector or a private industry auditor finds a deficiency, you have to respond and state what your corrective action will be. In both government and private programmes, follow-up inspections or auditor visits are usually required. This is to verify that improvements occurred after corrective actions were performed.

Examples of corrective actions performed daily in existing facilities:

- Establish procedures to prevent slipping and falling, such as washing the floor, or applying wood shavings.
- Rotate employees who perform the most physically strenuous jobs (state what the jobs are).

- Improve documentation of stunner maintenance to improve the percentage of animals effectively stunned with one application of the stunner (state changes to record keeping and stunner maintenance procedures).

Examples of corrective actions that are performed a single time:

- Purchase of new stunning equipment.
- Terminating the employment of an abusive truck driver.
- Installation of a non-slip flooring surface in a stun box, such as a ribbed rubber mat or welded steel rods.
- Construction of a solid barrier to prevent incoming livestock from seeing people and equipment movement through the headholder of the stun box (see Chapter 6).
- Changing lighting to improve animal movement (see Chapter 6).

Records – Written records of all corrective actions must be kept with the SOPs. Either paper or electronic records can be used.

Clear descriptions of non-compliances – Both government inspectors and private industry auditors should write up non-compliances in clear language. If numerical scoring is used, both the target score and the score the plant actually received should be stated. The animal welfare officer or other designated person, such as a quality assurance supervisor, should respond with a corrective action plan. Below are examples of clearly written and vague/poorly written non-compliance and corrective actions. Clear wording also makes it easier to determine how serious a problem is. In the example below, the clearly written description shows that the problem was really serious. The vague description makes the problem less obvious.

	Clearly written	Vague, not clear
Noncompliance	A pig squealed when it entered the scalding and no attempt was made to either re-stun it or stop the line.	Poorly stunned pig entered the scalding
Corrective action	Station a person at the end of the bleed chain before the scalding to shoot with a captive bolt any pig that shows any signs of starting to regain consciousness. That person will be trained using [state materials used] training materials.	Better supervision of stunning and bleeding

measures where the threshold values are based on peer-reviewed scientific literature (Grandin, 1998a, 2001, 2010; Losada-Espinoza et al., 2004, 2017). For slaughter and handling, there is now extensive

peer-reviewed literature that supports the thresholds for stunning, electric prod use, falling and vocalization that are found in the North American Meat Institute (NAMI) 2019 guidelines.

The booklet for ISO is *Animal Welfare Management: General Requirements and Guidance for Organizations in the Food Chain ISO/TS34700:2016*. It is an outline on how to set up your programme, but unfortunately it does not provide much practical guidance. It would be comparable to how each individual US slaughter plant had to develop its own individual Hazard Analysis and Critical Control Point plans to obey FSIS food safety regulations.

The section ‘Developing an Animal Welfare Plan’ discusses how to do a gap analysis of your plan. The directions are complicated and I will try to simplify them. A gap analysis is a method for looking at current performance and comparing it with a future performance goal. Your gap analysis should clearly identify your objectives for animal welfare (see chart in [Box 12.3](#) for example).

On-farm Welfare Problems That Can Be Assessed at the Abattoir

Livestock

Another area where welfare could be improved is the condition of the livestock that enter the plant (Grandin, 2015, 2017; Dahl-Pedersen *et al.*, 2018; Edwards-Callaway *et al.*, 2018; Forsgaard *et al.*, 2018). Some of the threshold-based, animal-based outcome measures that can be used to assess on-farm conditions are:

- percentage of animals that arrive downed and non-ambulatory;
- percentage of livestock with poor body condition (Edwards-Callaway *et al.*, 2018; Munoz *et al.*, 2018);
- percentage of dirty animals (Munoz *et al.*, 2018);
- percentage of lame (difficulty walking) animals (Welfare Quality, 2009; Edwards-Callaway *et al.*, 2017, 2018; Dahl-Pedersen *et al.*, 2018; Munoz *et al.*, 2018);
- percentage with neglected health problems;
- percentage with severe liver abscesses (the most severe liver abscesses have adhesions to the carcass and large parts of the carcasses have to be trimmed due to contamination; Herrick *et al.*, 2018); and
- other diseases, such as mastitis or parasites (Dahl-Pedersen *et al.*, 2018).

You could use the NAMI lameness scoring system for assessing lameness (Edwards-Callaway *et al.*, 2017). An advantage of this four-point scoring tool is that it provides an assessment of lameness severity and it still provides high inter-observer reliability. The scores are: (1) = normal; (2) = lame, keeps up with walking group; (3) = lame, does not keep up and lags behind; and (4) = almost non-ambulatory and can barely walk. There are also readily available body condition scoring charts for assessing skinny cull cows and sows. Scoring tools for dirty animals and neglected conditions, such as hernias in pigs, are readily available.

Box 12.3. Example of how a plant’s Animal Welfare Officers and Managers could create a gap analysis from their own records

Actual average scores in your abattoir	
Stunning	96%
Electric prods	23%
Falling	1%
Vocalization	7%
Future goals – average scores	
Stunning	99%
Electric prods	15%
Falling	0.2%
Vocalization	3%

You would also explain the corrective actions you used to improve scores and reduce the gap between actual scores and the goals. A possible example for improving stunning would be including the balancer

for a heavy pneumatic stunner as part of an enhanced maintenance programme. To reduce falling, you might replace the worn-out rubber mat in the stun box.

A large survey done in the USA showed that grain-fattened cattle had very low percentages of lame animals (Lee *et al.*, 2018). Observations by the author in 2018 also confirmed these results. Compiling averages across thousands of cattle may conceal very serious welfare conditions that a few poor producers are causing. Interviews with lairage workers clearly indicated that certain feedlots had greatly increased problems with lameness. On-farm issues that cause handling problems at the slaughter plant must be corrected at the farm. In a large pig slaughter plant, numbers of downed, non-ambulatory pigs were almost eliminated by changing on-farm practices. The following changes were made: (i) selection of breeding stock for good leg conformation; (ii) daily walking in the pens to get the pigs accustomed to people walking through them; and (iii) removal of beta agonists from the diet. When these observations were made, the temperature was over 38°C (100°F) with 41% humidity. During 1 h of observations, one pig arrived non-ambulatory on a truck and there were no downers in the stunning area. Approximately a thousand pigs were observed on this hot day. Before the on-farm production improvements were made, this same abattoir had five full-time people handling downers that were not able to walk.

In 2018, some of the most serious animal welfare issues that the author observed in US slaughter plants were issues that must be corrected at the farm. Producers who routinely deliver animals with serious welfare issues should be required to correct them. Dairy cows arriving in poor condition are still a major problem (Edwards-Callaway *et al.*, 2018).

Poultry

Many poultry welfare problems that occur on the farm can be easily assessed at the abattoir. There are problems related to housing and production:

- leg abnormalities, such as twisted or splayed;
- foot pad dermatitis;
- hock burn;
- skin lesions (breast blisters);
- plumage cleanliness; and
- cachexia (wasting syndrome), undersized.

Sources of information on these measures are Jacobs *et al.* (2016, 2017), Tuytens (2017) and Tuytens *et al.* (2018). Conditions caused by poor practices that occur during catching, transport or stunning have been covered in an earlier section of this chapter.

Conclusions

Maintaining a high standard of welfare of livestock and poultry during truck unloading, lairage, handling and stunning will require management to pay attention to many details of the procedure. Numerical scoring will help abattoir managers, regulatory officials and commercial auditors determine if practices are improving or deteriorating.

For the gap analysis, you could compare your baseline scores against goals for the future. Some of these goals could be based on published literature. There are many papers published in the peer-reviewed scientific literature. The ISO guidelines require periodic review of your animal welfare plan. During this review, you can determine if you are closing the gap between your current performance and your goals.

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13 Determining Unconsciousness and Insensibility in Commercial Abattoirs

TEMPLE GRANDIN*

Department of Animal Science, Colorado State University, USA

Summary

US and EU legislation require that an animal must be rendered insensible to pain before invasive dressing procedures start. If an animal shows any of the following clinical signs, it must be immediately re-stunned: (i) righting reflex or retains the ability to stand; (ii) species-specific vocalization; (iii) rhythmic breathing; (iv) menace/threat reflex or spontaneous (natural) blinking; (v) eyelash reflex; or (vi) corneal reflex (nictitating reflex in poultry). There is a transition zone between definitely conscious and definitely unconscious and brain dead. If an animal is re-stunned when it is in the transition zone, it is probably still insensible to pain. All of the above signs must be absent before invasive dressing procedures, such as skinning, scalding or dismemberment, are started.

Learning Objectives

- Determine if an animal is starting to return to sensibility.
- Determine when it is brain dead and invasive dressing procedures can be started.
- Provide easy-to-use guidance for people performing slaughter.

Introduction

An animal is unconscious if it is unable to respond to normal stimuli, including pain (von Hollenbon, 2010; AVMA, 2016). The definition used by the European Union's Food Safety Authority (EFSA) states (EFSA, 2013a–d):

Unconsciousness is a state of unawareness (loss of consciousness) in which there is temporary

or permanent damage to brain function and the individual is unable to perceive external stimuli (which is referred to as insensibility) and control its voluntary mobility and, therefore, respond to normal stimuli including pain.

Council Regulation (EC) 1099/2009 defines sensibility as the ability of the animal to feel pain (EFSA, 2013a–d). The American Veterinary Medical Association defines unconsciousness as loss of awareness that occurs when the brain loses the ability to integrate information (AVMA, 2019).

In the USA, according to the Humane Methods of Slaughter Act, 'all animals must be rendered insensible to pain by a single blow or gunshot or an electrical, chemical, or other means that is rapid and effective'. In both Europe and the USA the regulations clearly state that after stunning the animal must not experience pain.

This has been interpreted by the Food Safety Inspection Service (FSIS) of the US Department of Agriculture (USDA) that every application of a stunner must be effective. This is extremely difficult for a commercial abattoir to achieve. Enforcement has been increased due to recent pressure from non-governmental animal activist groups. This wording originated in both the 1958 and 1978 Humane Slaughter Acts. The same statute is still being used today. The US laws do not cover poultry. In many other countries and in Europe, humane slaughter laws include poultry.

The European wording is less strict and requires appropriate measures to be taken immediately if an animal is not properly stunned. Council Regulation (EC) 1099/2009 also states that:

Electrical stimulation shall only be performed once the unconsciousness of the animal has been verified.

* Email: cheryl.miller@colostate.edu

Further dressing or scalding shall only be performed once the absence of signs of life of the animal has been verified.

The EU regulations state that ‘loss of consciousness and sensibility shall be maintained until the death of the animal’.

Dr E.M. Terlouw, author of Chapter 14 in this volume, published a paper which reviewed many research studies on assessing consciousness and unconsciousness (Terlouw *et al.*, 2016). Some of the studies were done with EEG to record electrical activity from the brain. When new stunning methods are evaluated, research methods in the laboratory should use the most sensitive methods for assessing unconsciousness. The studies should use methods such as electroencephalography (EEG) or electrocochleography (ECoG) (Gevelmeyer *et al.*, 2016). Terlouw *et al.* (2016) concluded that there should be a differentiation between when an ani-

mal is fully conscious and when it is unconscious and is brain dead.

How EEGs Work

There are various methods for evaluating EEG tracings. A normal EEG in a conscious animal will have low-amplitude high-speed alpha waves (8–23 Hz). When the animal becomes unconscious, the waves change to high-amplitude slow delta waves (0.5–4 Hz) (Fig. 13.1). Brain death occurs when the EEG flatlines. Methods for evaluating EEG are described in Benson *et al.* (2012), Gibson *et al.* (2019), March *et al.* (2005), Vlisides and Mashour (2017) and Hagihira (2017). Either visual appraisal or specialized computer programs are used to determine when the alpha waves transition to delta waves. For EEG to be useful, the animal has to stay still to prevent movement artifact. Gibson *et al.* (2019)

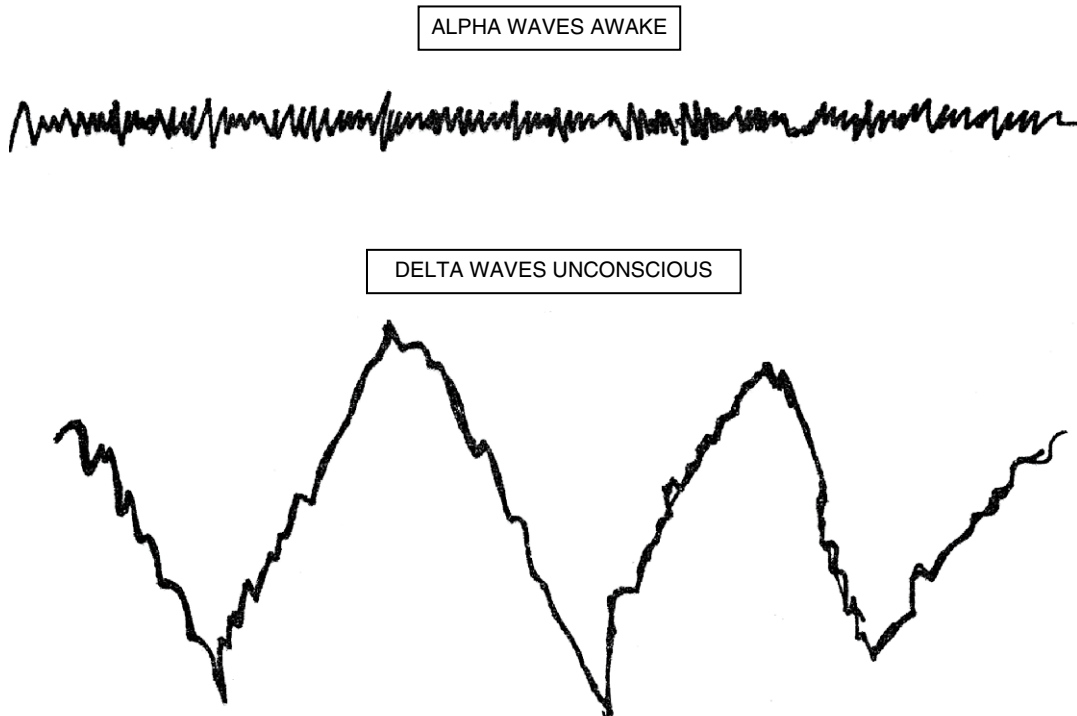


Fig. 13.1. Low-amplitude fast alpha waves in an awake conscious animal. High-amplitude slow delta waves under anaesthesia. These two waveforms are really distinct. The transition zone where the waves change from alpha to delta is not distinct.

classified EEG tracings as: (i) movement artifact; (ii) normal; (iii) transitional between consciousness to unconsciousness; (iv) high-amplitude low-frequency (delta) (unconscious) and (v) isoelectric – flatline brain dead. The new research still shows an indistinct transition zone between consciousness and unconsciousness.

Transition Zone Between Consciousness and Unconsciousness

There is a transition zone between the state of being fully conscious and brain death (AVMA, 2016; Terlouw *et al.*, 2016). VerHoeven *et al.* (2014) described the transition zone in a slightly different way: ‘The exact moment when unconsciousness sets in based on EEG is difficult to determine as the change is often gradual.’ A new document published by the AVMA (2019) stated that EEG data cannot provide a definite answer on the onset of unconsciousness. It occurs somewhere between behavioural unresponsiveness and flat (brain dead) EEG. Another way of explaining this is that it occurs at some point during the conversion of alpha waves to delta waves. When the animal is in the transition zone, it is probably insensible to pain. Regenstein (2017) used different words to describe the same concept. He stated there

should be a differentiation between ‘loss of the ability to feel pain’ and ‘loss of all reflexes in the head’. USDA defines unconsciousness as ‘not awake or aware, not able to respond to stimuli or the environment’ (FSIS, 2018). People often ask if unconscious and insensible are the same. The FSIS PHV refresher training course on consciousness and stunning (FSIS, 2018) states that unconscious = insensible. They are the same.

The US law states that stunning should always render the animal insensible to pain with a single shot. It is nearly impossible for commercial abattoirs to eliminate 100% of every brainstem reflex with a single application of the stunner. From the Terlouw *et al.* (2016) paper the US industry learned that if a second stunner application was applied when an animal was in the transition zone, they would probably still be in compliance, because the animal would most likely still be insensible to pain. This would be true if the only signs that were present were the corneal reflex, eyelash reflex to touch or rhythmic breathing.

The North American Meat Institute (NAMI) in Washington, DC published a chart in its voluntary guidelines for assessing unconsciousness during (NAMI, 2019) adapted here in [Table 13.1](#) and based on Terlouw *et al.* (2016) and other studies. For poultry, auditors from meat-buying customers often

Table 13.1. Assessing unconsciousness in livestock during slaughter (adapted from NAMI, 2017).

Possible state	Signs	Assessment	Action
<i>Definitely unconscious and brain dead:</i> ALL of the following signs are ABSENT	Menace reflex that occurs when a hand is waved in front of the eye without touch Eyelash reflex in response to touch Corneal reflex ^a Rhythmic breathing where the ribs move in and out at least twice	Unconscious	No action needed
<i>Unconscious but beginning transition back to consciousness:</i> ONE OR MORE of the following signs are PRESENT	Eyelash reflex in response to touch Rhythmic breathing where the ribs move in and out at least twice Corneal reflex ^a	Unconscious	Re-stun immediately
<i>Definitely conscious:</i> ANY of the following signs are PRESENT	No loss of posture (LOP) / animal standing Righting reflex on the rail ^b Spontaneous, unprovoked blinking Menace reflex that occurs when a hand is waved in front of the eye without touching Eye pursuit of a moving object	Conscious	Re-stun immediately

^aFor cattle, a finger may be used to test the corneal reflex. Because pigs and sheep have small eyes, a small blunt object like a pencil eraser or something similar may be used to touch the surface of the eyeball

^bSee [Figs 13.2](#) and [13.3](#)



Fig. 13.2. A properly stunned bovine hanging on the rail has a straight back and a limp floppy head. Cattle and pigs will hang straight as shown in this photo. Some types of sheep will not hang straight due to strong suspensory ligament in the back of the head. In all species, the head and neck should be loose and floppy. (Photo courtesy of Temple Grandin.)



Fig. 13.3. Fully conscious bovine hung on the rail with an arched back righting reflex. Its back is arched and it is raising its head because it is fully conscious. The person doing the shackling failed to re-stun it before hoisting. This is a serious violation of animal welfare laws. It is important for people stunning and bleeding livestock to know what a righting reflex on the rail looks like. A single, properly applied stunning method will abolish the arched back righting reflex. This applies to all stunning methods. (Photo courtesy of Temple Grandin.)

audit suppliers and they will hold poultry companies to the same standards as plants slaughtering livestock. This is a situation where the use of private standards by commercial customers are improving welfare issues not covered by legislation.

Agreement Between USDA, EFSA, AVMA and NAMI on Consciousness Indicators for Livestock

There are some slight differences between researchers on the exact indicators that are in the transition zone between being conscious, and unconscious and brain dead. A commercial slaughter plant is not a research laboratory with an EEG. Therefore, indicators used under commercial conditions *must* be really conservative. The main area of possible disagreement is with spontaneous unprovoked (natural) blinking and the menace/threat reflex. The researchers' results are mixed. It is the author's opinion that to ensure that animals are unconscious under commercial conditions, these two indicators have been placed in the 'definitely conscious' category. When all types of stunning are done correctly, it is easy to completely abolish spontaneous blinking and the menace/threat reflex (Grandin, 2001, 2002). A single application of proper captive bolt or gunshot will eliminate the corneal reflex (Grandin, 2002; AVMA, 2016; Kamenik *et al.*, 2019). The corneal reflex and pupillary reflex to light may remain in a few properly stunned unconscious pigs that have been stunned with electricity (Vogel *et al.*, 2010). Corneal reflex, palpebral reflex and pupillary response to light may occur in unconscious animals after religious slaughter (Verhouvern *et al.*, 2014).

The corneal reflex can occur in unconscious humans or animals (Vogel *et al.*, 2010). Vogel *et al.* (2010) reported that, with electrical stunning, it was not possible to eliminate all the brainstem reflexes in every single pig, prior to bleeding. Since the process of returning to consciousness is starting, the animal must be immediately re-stunned to prevent return to consciousness. Re-stunning with a captive bolt should be done immediately.

All reflexes in the eyes and head must be absent before carcass processing or invasive dressing procedures

To comply with EU (EFSA, 2004), OIE (2019), USDA (FSIS, 2017), AVMA (2016, 2019) and

NAMI (2017) regulations and guidelines, *all* reflexes in the head must be absent. To say it simply: *the head must be dead* before carcass processing begins. Invasive dressing procedures (carcass processing) include but are not limited to scalding, skinning, feather removal, limb removal, head removal and other procedures. This applies to all forms of slaughter, both stunning and religious slaughter without stunning. Bleeding the animal ensures brain death and it will eliminate eye and brainstem reflexes. For conventional slaughter with stunning, the EU requires re-stunning if the animal shows any of the signs listed below (EFSA, 2013a–d). The most common re-stunning method after all types of stunning is captive bolt. For both conventional and religious slaughter, without stunning, all of the reflexes below must be absent before invasive carcass processing.

- Menace/threat reflex – eye blinks when hand is waved in front of it. No touching. To learn what an eye blink looks like, observe live animals in the lairage (Fig. 13.4). During religious slaughter of cattle, this reflex may be difficult to interpret due to blood in the eye (see Chapter 14). This is especially a problem when the animal is inverted on to its back. Natural spontaneous blinking in poultry is an easy-to-use measure in a commercial slaughter plant. It is an indicator of sensibility in poultry (Girasole *et al.*, 2016).
- Corneal reflex to touch.
- Floppy-head – loss of neck tension in poultry hanging inverted on the shackle lines. Easy-to-use measure in a commercial poultry plant.
- Response to nose prick, or comb pinch in poultry.

- Rhythmic breathing – sides of the body move in and out. Do not confuse with gasping like a fish out of water.
- Failure to collapse and lose posture (ability to stand). Note that some papers use the term loss of balance instead of loss of posture (LOP). There are situations where the animal will fall and then get back up. This may be referred to as loss of balance. The animal is definitely unconscious when it permanently loses the ability to stand. This may also be called durable loss of posture, or loss of righting reflex (LORR) (AVMA, 2019).
- Palpebral (eyelash) reflex (nictitating membrane reflex in poultry).
- Species-specific vocalization absent.
- Nystagmus vibrating eye – not to be confused with true blinking (sign of a shallow stun with captive bolt) (Verhoeven *et al.*, 2014). Acceptable in electrically stunned animals.

Boxes 13.1, 13.2 and 13.3 contain signs that can be used easily in a commercial abattoir.

Ignore kicking: look at the head

In cattle, pigs, sheep and other mammals: *ignore kicking*. Kicking reflexes can occur in animals after the head is removed or the spinal cord has been severed (Terlouw *et al.*, 2015). The circuits that enable animals to walk are located in the middle of the spine (Grillner, 2011; Bouvier *et al.*, 2015; Martin *et al.*, 2018). Terlouw *et al.* (2015) discovered that kicking still occurs after the spinal cord is severed at the base of the skull. Foreleg movement



Fig. 13.4. People slaughtering animals must learn what spontaneous natural blinking and a response to the menace/threat reflex looks like. The best way to learn is to go into the lairage and look at live animals blinking. The menace reflex test is conducted by waving a hand in front of the eye without touching. It should not be confused with nystagmus (vibrating eye). (Photo courtesy of Temple Grandin.)

Box 13.1. Signs of insensibility (unconsciousness) in animals shot with properly applied captive bolt or gunshot that causes physical brain concussion (Grandin, 2015)

All four signs **MUST BE ABSENT** before invasive dressing procedures are started.

Rhythmic breathing

Occurs if ribs move in and out at least twice. Do not confuse with gasping (like a fish out of water), which may occur in properly stunned animals.

Natural blinking

Eye makes a fully open-and-close cycle like live animals in the lairage. Test by waving a hand in front of the eye (menace reflex). Do not touch the eyes. Nystagmus (vibrating eye) or weak corneal reflex may be present in unconscious animals. These reflexes must be absent before invasive dressing procedures are started.

Vocalization

Bellow, moo, squeal. It is permissible to have a small grunt due to chest compression when the animal falls.

Righting reflex (LOP or LORR)

When hung on the rail this can be observed as an arching of the back and sustained backward lifting of the head (Fig. 13.3). This should not be confused with a momentary flop of the head, which occurs when the back legs exhibit reflexive kicking. If the animal is on the floor, complete loss of posture (LOP) and loss of the ability to raise its head or stand.

Box 13.2. Signs of insensibility (unconsciousness) in animals stunned with electricity, CO₂ or other gases and LAPS, for methods that do not cause physical brain concussion (Grandin, 2015, updated)

All four signs **MUST BE ABSENT** before invasive dressing procedures are started.

Rhythmic breathing

Occurs if ribs move in and out at least twice. Do not confuse with gasping (like a fish out of water), which may occur in properly stunned animals.

Natural blinking

Eye makes a fully open-and-close cycle like live animals in the lairage. Test by waving a hand in front of the eye (menace reflex). Do not touch the eyes. Nystagmus (vibrating eye) or weak corneal reflex may be present in properly stunned animals. These reflexes must be absent before invasive dressing procedures are started.

Vocalization

Bellow, moo, squeal. It is permissible to have a small grunt due to chest compression when the animal falls.

Righting reflex (LOP or LORR)

When hung on the rail this can be observed as an arching of the back and sustained backward lifting of the head (Fig. 13.3). This should not be confused with a momentary flop of the head, which occurs when the back legs exhibit reflexive kicking. If the animal is on the floor, complete loss of posture (LOP) and loss of the ability to raise its head or stand.

Box 13.3. Signs of insensibility (unconsciousness) in properly stunned chickens (Grandin, 2015, updated)

- No nictitating membrane reflex – inner third eyelid closes in response to touching the edge of the outer eyelid.
- No spontaneous (natural) eye blinking that looks like eye blinks in live poultry in the lairage (easy to use in a commercial plant).
- Loss of muscle tone in jaw and neck (floppy) (easy to use in a commercial plant).
- No rhythmic breathing – some gasping like a fish out of water is permissible.
- No response to comb pinch.
- Electrical stunning: constant rapid tremors with wings held close to the body (HSA, 2016).

This is for electrical stunning only. When the chicken starts to recover, the wings will extend into extended flapping.

Recommendations based on EEG (brainwave) studies that were used to validate reflexes that could be observed at slaughter with signs of unconsciousness in chickens (Erasmus *et al.*, 2010; Johnson, 2014; Sandercock *et al.*, 2014; Poultry Industry Council, 2016; Martin *et al.*, 2019). Girasole *et al.* (2016) is an excellent review of the relationship between electrical stunning methods and return to sensibility.

may sometimes occur during knife insertion for bleeding. This is a reflex (Terlouw *et al.*, 2015).

Vogel *et al.* (2010) explained that the corneal reflex is the involuntary eyelid-closure response to protect the eyes from injury. There are two cranial nerves involved, one sensory and one motor, which converge in the brainstem. The corneal reflex occurs when a signal is sent from the brainstem to the eyelids to trigger closure. The corneal reflex only indicates brainstem activity, which is not indicative of consciousness by the stunned animal. Electrically (Vogel *et al.*, 2010) or gas-stunned animals with a weak corneal reflex triggered by the tip of a pen and no other signs of return to sensibility would be in a state similar to general anaesthesia. To prevent return to consciousness, they should be immediately re-stunned. If the animal has spontaneous, natural blinking that occurs when the eye is not touched, the animal is either definitely sensible (conscious) or close to regaining consciousness and must be re-stunned (Verhoeven *et al.*, 2014, 2015). People who are assessing insensibility should look at live animals in the lairage so that they will know what spontaneous blinking looks like (Fig. 13.4). For animals stunned with either gunshot or penetrating or non-penetrating captive bolt, the corneal reflex and all eye movements must be absent (Gregory, 2008; AVMA, 2016). The eyes should open into a wide, blank stare and not be rotated (Gregory, 2008). Do *not* use a finger or other thick blunt object to poke the eyes of animals with small eyes, such as pigs and sheep, when testing small animals for eye reflexes. This causes confusing signs that are difficult to interpret (Grandin, 2001). A finger may be used on animals with large eyes, such as cattle. Multiple indicators of return to consciousness must all be absent (Verhoeven *et al.*, 2015). Never rely on a single indicator.

The signs of insensibility in Boxes 13.1, 13.2 and 13.3 can be used when assessing stunning efficacy in cattle, pigs, sheep and other mammals (HSA, 2016a, 2016b, 2018). Additional information can be found in Gregory (2008) and Verhoeven *et al.* (2015).

Consciousness in the Fetus

There is concern that fetuses in livestock may suffer during slaughter. The EFSA Panel on Animal Health and Welfare (EFSA, 2017) reported that 3% of dairy cows, 1.5% of beef cows, 0.5% of sows, 0.8% of sheep and 0.2% of goats are in the final

third of pregnancy when they arrive at the slaughterhouse. When fetal blood is collected, the recommended procedure is to leave the fetus inside the uterus until 15–20 min after the maternal neck cut (OIE, 2019). To reduce the possibility of the fetus becoming conscious, it should not be allowed to breathe air (Mellor and Gregory, 2003). A late-stage fetus that shows signs of life, or if there is any doubt about consciousness, requires stunning with a captive bolt (OIE, 2019). There is an extensive review of the literature in EFSA (2017).

Locations on the Processing Line to Evaluate Unconsciousness

The EU requires that the stunner operator, the shackler and the bleeder must have certificates to show that they have been trained to determine the signs that an animal is unconscious or starting to return to consciousness. For all stunning methods, the animal must be checked in three locations: (i) after release from the stun box, restrainer or CO₂ machine; (ii) at bleeding; and (iii) before invasive dressing procedures (carcass processing) starts. The checks should be done by two different people, a line slaughter employee and the animal welfare officer (EFSA, 2013). For religious slaughter without stunning, the animal should be checked before release from the restraint box and before invasive dressing procedures start.

Conclusions

When stunning is done correctly, all the indicators of return to consciousness will be absent. To maintain high standards, stunning equipment must be well maintained and applied by trained people. Poor maintenance of stunning equipment is a common cause of failure. The management of the abattoir must have a commitment to maintaining high standards.

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14 The Physiology of the Brain and Determining Insensibility and Unconsciousness

E.M. CLAUDIA TERLOUW*

Clermont Auvergne University, INRAE, VetAgro Sup, UMR Herbivores, France

Summary

In many countries, slaughter mostly involves two interventions: the animal is stunned to induce a loss of consciousness and then bled to induce death. In the context of religious slaughter (halal and shechita), animals may not be stunned before bleeding. In this case, the loss of blood first induces a loss of consciousness and then death. In certain cases of halal slaughter, the animal is stunned before or just after religious throat cutting to accelerate loss of consciousness.

Scientific studies show that mammals and birds are able to experience positive and negative emotions. The induction of unconsciousness before bleeding ensures that the animal does not experience pain, fear or other negative emotions during the slaughter process. The stunned, unconscious animal is insensitive to stimulations coming from its body or the environment: the brain is no longer capable of processing sensory information.

Animals showing any of the indicators of consciousness, of return to consciousness or risk of return to consciousness must be immediately re-stunned. The indicators of a conscious animal are: standing posture; head righting/righting reflex; species-specific vocalization; and response to menace/threat test. Indicators of risk of return to consciousness are: eye tracking; repeated spontaneous blinking; eyeball rotation or nystagmus; incomplete righting reflex; corneal reflex; or rhythmic breathing. Indicators of unconsciousness or death are: permanent loss of standing posture; absence of corneal reflex; absence of rhythmic breathing.

Learning Objectives

- Understand major parts of the brain associated with consciousness.
- Learn basic principles of stunning.
- Determine unconsciousness and death.
- Learn differences between animal species.
- Understand loss of consciousness during slaughter without stunning.

The Central Role of the Brain

Before describing how stunning or direct bleeding induces unconsciousness, the major parts of the brain and their relationship with normal, conscious functioning are presented.

Life consists of making of decisions, expressed in behaviour. An animal decides whether it should rest, care, eat, drink, look for a partner or for shelter, whether the ongoing behaviour should continue or be interrupted. The brain is the decision-making organ and it does so by combining all the information it has collected through different modalities. Various senses – hearing, seeing, smelling – allow the collection of information relating to the environment. Other sensors allow the collection of information on body condition. Oxygen and carbon dioxide sensors, baroreceptors and lung stretch receptors inform the brain in real time about the haemodynamic state of the body, allowing constant adjustments. Specialized sensory neurons give information on mechanical pressure and nociceptors on the presence of noxious stimuli on the body.

* Email: claudia.terlouw@inrae.fr

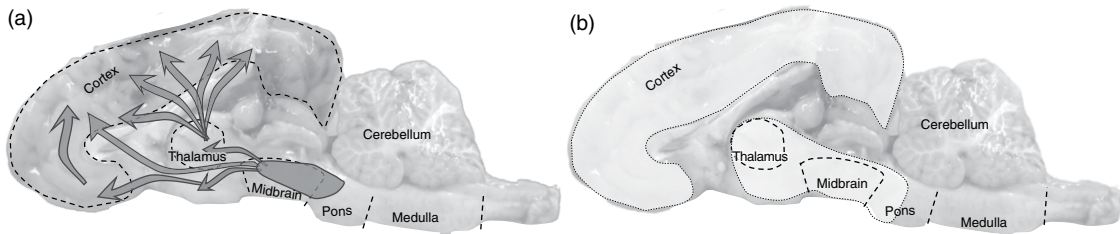


Fig. 14.1. Sagittal cut of a sheep brain (fresh). (a) The ascending reticular activating system (dark grey area and arrows) consists of three major pathways. One passes via the thalamus located just above the brainstem which in turn projects massively on the cortex (mammals) or pallium (birds) (Northcutt, 1984; Parvizi and Damasio, 2001). Another runs ventrally via the hypothalamus and basal forebrain, which in turn projects onto the cortex. The third pathway projects directly on the cortex (Parvizi and Damasio, 2003; Weiss *et al.*, 2007; Brown *et al.*, 2012). (b) Injury to the thalamus and hypothalamus, midbrain and/or rostral pons leads to impaired consciousness (Moruzzi and Magoun, 1949; Batini *et al.*, 1958; Gottesmann, 1988; Parvizi and Damasio, 2003). Impairment of large regions of the cortex, particularly the associative cortices, also causes unconsciousness (Laureys, 2005). Shaded areas indicate regions essential for consciousness. (Photo courtesy of V. Paulmier and C. Terlouw.)

Proprioceptors provide information about joint angles, muscle length and tension, which inform the brain on the posture and the spatial orientation of the body. Chemical sensors in the gut provide information about the digestive state. These sources of information, and others related to memory for example, are constantly compiled by the brain into an integrated coherent image in order to take appropriate decisions.

To carry out the integration of information properly, the brain has a highly organized architecture containing many specialized structures, but which at the same time are strongly interconnected to allow information aggregation. Mammals, humans included, have the same major brain structures. In its simplest form we can distinguish the forebrain, the midbrain and the hind-brain (Fig. 14.1; Box 14.1). The avian brain has many brain structures that are homologous to mammalian brain structures. For example, the avian pallium is homologous to the mammalian cortex.

Brain Structures Involved in Consciousness

The cerebral cortex

Antonio Damasio defined consciousness as ‘a state of mind in which there is knowledge of one’s own existence and of the existence of surroundings’ (Damasio, 2010). The cortex is the outer layer of the mammalian brain; it has a folded

appearance and is essential for conscious experiences. The visual, auditory, somatosensory, gustatory and olfactory cortices are the primary cortices, receiving, generally via the thalamus (Box 14.1), direct information from the senses. Their role is the first unscrambling of the signals. The primary motor cortex sends signals to the muscles, via the basal ganglia, allowing the animal to act on what it has perceived. Before the reaction, the integration of many types of information, on the environment, the body state, emotions and memory amongst others, takes place. This is the role of association cortices; they integrate and interpret information of primary areas, conceptualize information in a wider context and plan appropriate responses. The correct functioning of primary and associative cortices is necessary to know, understand and give a sense to what is perceived; to have a conscious perception of the environment and of the self (Crick and Koch, 2003; Laureys, 2005).

The thalamus

The thalamus is placed centrally in the mammalian and avian brain. It is an essential relay station for visual, auditory, gustatory, somatosensory and motor information for the cortex (McCormick and Bal, 1994; McAlonan *et al.*, 2008; Huart *et al.*, 2009; Rees, 2009). The thalamus is involved in shifting attention from one stimulus to another one, which may seem more relevant or which attracts more, such as bright objects. Impairment of

Box 14.1. The major brain structures and their functions

The hindbrain is the lowest part of the brain (Fig. 14.1). It contains the cerebellum, of which the main function is to coordinate muscle movements, the medulla oblongata (or medulla), involved in the regulation of respiration and blood circulation, and the pons, involved in facial expression, sensation in the face, auditory processing, certain eye movements, respiration and sleep, among others.

The midbrain is situated just above the pons (Fig. 14.1). It is involved in eye movements, focusing of the eye lens, and auditory and visual processing. The midbrain, the pons and the medulla form together a structure called the brainstem. The brainstem and cerebellum play a major role in the maintenance of posture and balance.

The mammalian forebrain contains the cortex, involved in complex information processing such as remembering and planning, and the expression of purposeful behaviour, for example nest-building or searching for food or water (Fig. 14.1). In humans, the cortex is in charge of thinking, speaking and reasoning. It contains several subcortical structures, such as the hippocampus, involved in memory, the

thalamus, which is an important relay station of most sensory and motor signals to the cerebral cortex, and the hypothalamus, which controls fluid and electrolyte balance, food ingestion, energy balance, reproduction, thermoregulation and immune and emotional responses. It further contains the basal ganglia, involved in motor functions.

The avian brain contains homologues of mammalian neocortical structures with similarities in connectivity and functional organization (Jarvis *et al.*, 2005). The avian pallium receives information relative to the environment and the body state and projects to the brainstem and spinal cord, so that the organism can adapt, physiologically and behaviourally, to the incoming information. Like mammals, birds express complex cognitive behaviour. They can distinguish images that they can classify according to their content or group them according to abstract concepts, such as 'similar' or 'different'. Pigeons, for example, distinguish between photos containing humans and those that do not. Pigeons, hens and quail are also able to solve complex problems that require the application of a rule (Emery, 2006).

the thalamus and subthalamic regions abolishes consciousness (Moruzzi and Magoun, 1949; Gottesman, 1988) (Fig. 14.1).

the ascending reticular activating system (rostral pons, midbrain and their projections) abolishes consciousness (Fig. 14.1).

The reticular formation and the ascending reticular activating system

The reticular formation plays an essential role in the level of arousal and consequently in consciousness (Fig. 14.1). It is located in the central and dorsal part of the brainstem, extending from the lower medulla to the upper midbrain, and consists of a network of interlacing neural fibres (Parvizi and Damasio, 2001). Projections arising from the reticular formation and surrounding structures activate the cortex, allowing it to function correctly and have conscious perception; it is called the ascending reticular activating system. Non-mammalian vertebrates, including birds, have similar structures (Ten Donkelaar and De Boer-Van Huizen, 1981; Northcutt, 1984). The function of the ascending reticular activating system is the maintenance of wakefulness and complex functions including motivation, attention, learning and memory (Zeman, 2001; Damasio, 2010; Brown *et al.*, 2012). Impairment of

Brain Structures Involved in Emotions and Pain

Scientific studies on animal behaviour and physiology as well as brain anatomy and function show that all mammals are able to experience positive and negative emotions (Paul *et al.*, 2005; Boissy *et al.*, 2007). Emotions are the driving force behind motivational states (Morgane *et al.*, 2005). Emotions are processed by the limbic system, which consists of several cortical and subcortical structures essentially located in the forebrain (Morgane *et al.*, 2005). The limbic system exists in humans and also in non-human mammals (LeDoux, 2000). The avian brain contains structures with similar functions as the mammalian limbic system and behavioural studies show that birds are capable of positive and negative emotions (Lowndes and Davies, 1996; Jarvis *et al.*, 2005; Zimmerman *et al.*, 2011). Pleasant experiences are associated with relatively greater activation in some of these limbic structures,

Box 14.2. The emotional and sensory components of pain

A stimulus is noxious when it can cause tissue damage. Nociceptors in the skin, joints, muscles and viscera are specialized nerves that transform noxious stimuli, whether chemical (often related to tissue lesions), mechanical or thermal, into a nervous message, which travels from its peripheral origin via the spinal cord to the brain, where the signal is interpreted. The sensory component (the type, location and intensity of the stimulus) of the pain experience is interpreted by the somatosensory cortices and the emotional (the unpleasantness of stimulus) by the limbic cortices (Bushnell *et al.*, 2013).

Local brain lesions may abolish one of the two components of pain. Ploner *et al.* (1999) described a patient with partial lesions of the somatosensory cortices. When thermal stimulation was applied on the body,

the patient had no information on the location, type and intensity of the stimulus. She did not even know there was a stimulus; she reported an 'unpleasant feeling' without being able to characterize its cause. She experienced the negative emotion, but did not understand the origin, lacking the nociceptive component.

The role of the limbic cortex in the emotional aspects of pain perception is illustrated by lesions in the limbic cortex of patients suffering severe incapacitating pain, interventions that were carried out in the past. When questioning the patients after the intervention, they reported that pain was still present, but no longer 'bothersome' (Foltz and White, 1962). Strictly speaking, we cannot speak of pain here because these patients perceive only the sensory and not the emotional component.

unpleasant experiences with activation in other limbic structures (Wager *et al.*, 2008). The term 'stress' refers to the presence of negative emotions, which occur when the animal feels threatened, whether the threat is real or imaginary. Stress is further associated with behavioural and physiological changes, which allow the animal to respond to the threat.

Pain is defined as 'an unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage' (International Association for the Study of Pain). Pain signals are difficult to ignore; as indicated by the definition, pain perception is associated with potential tissue lesion and danger and logically needs attending to (Eccleston and Crombez, 1999). By definition, pain refers to the situation where both the sensory and emotional components are perceived (Box 14.2). The bird pain system shows much similarity to that of mammals (Gentle, 1992).

The Basic Principles of Stunning

Stunning must induce a state of unconsciousness, which lasts until death is induced through exsanguination. The normal living brain is permanently active; it involves the permanent depolarization (losing electrical charge) and repolarization (regaining electrical charge) of its neurons. During unconsciousness, the electrical activity of the cortex is much reduced and may even be nearly absent (Newhook and Blackmore, 1982a,b; Raj *et al.*,

2006; Lambooi *et al.*, 2012). Depending on the method used, unconsciousness is induced by widespread dysfunction of the cerebral hemispheres, of which the cortex is part, or by impairment of the ascending reticular activating system, abolishing its stimulating effect on the cortex (Fig. 14.1). Particularly, damage to the thalamus and hypothalamus, or in the region of the midbrain and rostral pons, causes unconsciousness (Moruzzi and Magoun, 1949; Batini *et al.*, 1958; Parvizi and Damasio, 2003).

Mechanical stunning: the penetrating captive bolt

The penetrating captive bolt is a metal rod of generally 80–120 mm long and 12 mm thick and is used for any species, generally routinely for cattle and sheep and as a back-up stunning method for pigs (Kamenik *et al.*, 2019). It is contained in a stun gun placed against the forehead of the animal. The correct firing of the captive bolt causes unconsciousness due to one or several of the following effects: impact, mechanical destruction of parts of the brain, and widespread brain haemorrhage (Table 14.1).

The impact of the bolt on the skull sends a shock-wave through the brain, repeatedly reflected and refracted by the skull and the boundaries between brain structures (Fig. 14.2). These reflections and refractions jumble the waves so that their crossings augment and cancel each other. Pressure gradients lead to tears and lesions in the brain tissue and disturbances

Table 14.1. Physiological events contributing to reversible or irreversible loss of consciousness, for the different stunning methods (not relevant for animals killed by the stunning method).

Stun technique	Event	Consequence	Reversibility of the effects in the short term
Captive bolt	Shock wave	Uncontrolled influx and efflux of ions: depolarisation of nerve cells	Reversible
		Slowing of energy production by the cells	Reversible
	Compression: decreased functioning of nerves and circuits	Reversible	
Captive bolt	Bolt entering and exiting brain	Compression: decreased functioning of nerves and circuits	Potentially reversible
		Tears and rupture of brain tissue	Irreversible
	Shearing of vessels	Irreversible	
Captive bolt	Brain haemorrhage	Insufficient blood circulation: lack of glucose and oxygen leading to lack of energy in the brain cells	Irreversible
		Compression: decreased functioning of nerves and circuits	Irreversible
	Electrical	Current passing through the brain	Synchronised depolarisation of nerve cells, spreading to other brain regions
Current passing through the heart (head-body stunning only)		Heart fibrillation	Potentially reversible
Current passing through the spinal cord (head-body only)		Weakness of skeletal muscle	Reversible
CO ₂	Absorption and dissolution of CO ₂ in the blood	Acidification of brain cells	Reversible

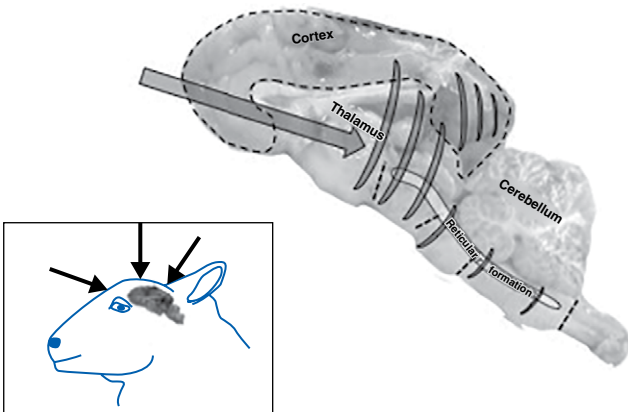


Fig. 14.2. Schematic illustration of the compression of brain tissue when the bolt enters the sheep brain frontally. Insert: possible positions of the stun gun on the sheep head (after Grandin, 2017). Notice that particularly with the frontal position the brainstem is easily missed if the gun is incorrectly oriented.

in the blood flow (Gibson *et al.*, 2015b; Martin, 2016; Terlouw *et al.*, 2016a). The impact causes a depolarization of the neurons of the cerebral hemispheres and potentially of the brainstem (Takahashi *et al.*, 1981; Katayama *et al.*, 1990; Martin, 2016). It disrupts normal cell function, particularly the production of energy and thereby slowing the potential repolariza-

tion of the neurons (Posner *et al.*, 2008). During subsequent deceleration, the cerebrum may swing on the brainstem, stretching and tearing it (Martin, 2016). The simple impact caused by the penetrating captive bolt is insufficient to obtain a long-lasting state of profound unconsciousness. The non-penetrating mushroom-shaped captive bolt induces

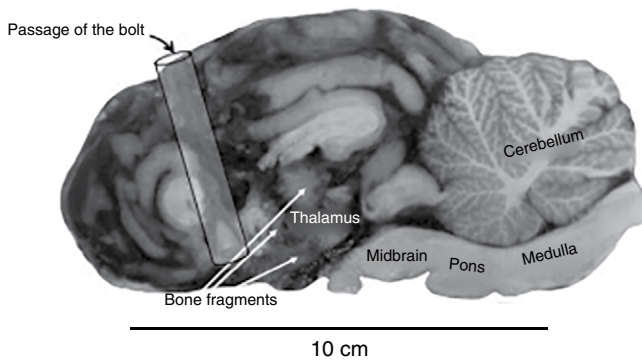


Fig. 14.3. Sagittal cut of a Charolais cow's brain (frozen after being removed from the skull) following effective captive bolt stunning, showing local destruction, bone fragments and widespread haemorrhage (dark aspects). The bolt did not reach the brainstem. (Photo courtesy of N. Bouko-Levy.)

unconsciousness through its impact via the skull on the brain, but its success rate is lower than that of the penetrating bolt (Gibson *et al.*, 2019).

The penetrating bolt causes further local fragmentation of the skull and pushes bone fragments, hair, skin and brain tissue through its trajectory (Terlouw *et al.*, 2016a). If the bolt reaches the thalamus and/or brainstem, it destroys part of the reticular formation and part of the ascending reticular activating pathways (Blackmore, 1979; Daly *et al.*, 1987; Daly and Whittington, 1989; Finnie, 2001) (Fig. 14.1), although the brainstem may be easily missed (Fig. 14.2) (Gilliam *et al.*, 2012; C. Bourguet, personal communication). The retraction of the bolt temporarily leaves a void in the tunnel created by its passage that sucks in the surrounding brain tissue, causing further tearing of axons and blood vessels (Terlouw *et al.*, 2016a).

Secondary damage, particularly widespread haemorrhage in many parts of the brain, is a major additional effect both for penetrating and non-penetrating stunning (Oliveira *et al.*, 2018; Kamenik *et al.*, 2019) (Fig. 14.3). Haemorrhage causes increased pressure on brain structures and further deprives them of blood supply; both severely hamper normal functioning of the neurons of the brain (Ommaya *et al.*, 1964; Terlouw *et al.*, 2016a). Cattle may be correctly stunned even if visual inspection of the brain indicates that the bolt has not caused direct damage to the brainstem. In these animals, generally widespread haemorrhage is observed in the cerebral ventricles and subdural area, surrounding the brain, while pinpoint haemorrhage may be observed in the white fibre tracts of the brainstem or other parts of the brain.

Mechanical stunning causes unconsciousness before the animal can perceive pain or fear-inducing stimuli. As an example, in a Holstein cow (Fig. 14.4),

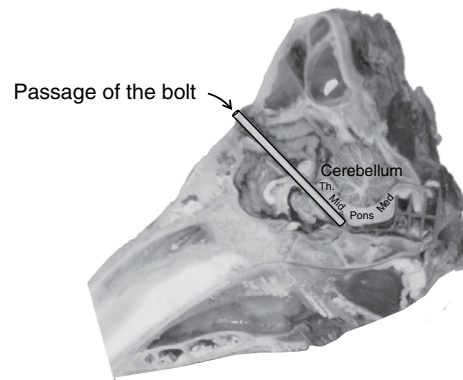


Fig. 14.4. Sagittal cut of a Holstein cow's head (frozen in the skull). The representation of the bolt is 9 cm long and demonstrates the distance to the brainstem. Th., thalamus, Mid., midbrain, Med., medulla. (Photo courtesy of C. Mallet.)

the distance between the skin of the forehead and the brainstem is approximately 7.5 cm and bolt velocities are between 27 and 61 m/s (Dörfler *et al.*, 2014; Gibson *et al.*, 2015b; Oliveira *et al.*, 2017). Hence, the brainstem is reached in 30 ms or less. The initial effect of the shock wave reaches deep brain structures within a few milliseconds (Chafi *et al.*, 2011; Zhu *et al.*, 2013; Martin, 2016). Thus, the delay to induce unconsciousness is much shorter than the 250 and 400 ms needed for conscious information processing (Box 14.3) and the animal has no conscious perception of the shot.

Stunning with an electrical current

Electrical stunning is used for sheep, poultry and pigs and in certain countries for calves or adult cattle. With this method, an electrical current of

Box 14.3. The time needed to be conscious of information arising from the body or the environment

Signals of the environment or arising from the body need time to travel towards the brain and to be consciously processed. The first, immediate pain stimulus travels towards the brain with a speed of 5–30 m/s while secondary, slow pain signals travel at speeds of below 2 m/s (Purves *et al.*, 2004). Immediate pain needed 128 ms to travel from the hand receiving the painful stimulation to the somatosensory cortex (i.e. speed of about 8 m/s) and 271 ms to be processed, before the person could react (Ploner *et al.*, 2006). Tactile stimuli travel faster, 30–70 m/s, and needed 36 ms to travel from the hand to the cortex (i.e. speed of about 30 m/s) but 333 ms to be processed (Ploner *et al.*, 2006). Hence, following application, tactile and painful stimuli needed between 370 and

400 ms to be consciously processed, but this may be shorter if the distance between the stimulus site and the brain is shorter.

Visual, auditory and olfactory stimuli carry information on the environment that may indicate the presence of danger and therefore cause fear. Conscious perception of olfactory, visual or auditory information generally takes place 250–400 ms after the stimulus presentation (Comerchero and Polisch, 1999; Chennu and Bekinschtein, 2012). Thus different signals need variable times to reach the cortex, but the total time needed (travelling plus processing time) for conscious processing of sensory information is relatively standardized across modalities, ranging between 250 and 400 ms.

sufficient intensity crosses the brain, causing a generalized epileptiform seizure, followed by a brief period with greatly diminished brain activity, reflecting the massive and synchronized depolarization of the neurons (Blumenfeld, 2005) (Table 14.1). To induce unconsciousness, the seizure needs to be generalized, that is, to spread, and involve various brain structures such as the brainstem, thalamus and cortex (Lambooij and Spanjaard, 1982; Blumenfeld *et al.*, 2003; Blumenfeld, 2005; Enev *et al.*, 2007).

Other consequences include the release of neurotransmitters, particularly gamma-aminobutyric acid (GABA). Neurotransmitters are necessary for the transfer of information between neurons and the role of GABA is to slow brain activity; its release contributes to the state of unconsciousness (Cook *et al.*, 1995; Treiman, 2001; Blumenfeld, 2005; Terlouw *et al.*, 2016a). The blood circulation in the brain is modified and, in certain brain regions, blood flow may be insufficient to cover oxygen needs (Ingvar, 1986; Enev *et al.*, 2007; Schridde *et al.*, 2008; Posner *et al.*, 2008).

There are two types of electrical stunning: head-only and head-body. In the first case, two electrodes are placed on either side of the head of the animal and the current crosses the brain. Following head-only stunning, after the seizure convulsions subside, the polarization of the neurons and metabolic brain state are restored, and the animal progressively regains consciousness (Posner *et al.*, 2008; Vogel *et al.*, 2011; Gibson *et al.*, 2016). In the case of head-body electrical stunning, a current crosses the brain but also the heart. For sheep and pigs, two electrodes are placed

on the head of the animal and a third on the chest, leg, sternum or back, depending on the species. Birds are hung by their legs on metal shackles suspended on a rail. The head is immersed in an electrified bath and the current flows between the head and legs. For adult cattle, electrical stunning also generally involves a head-body technique (Weaver and Wotton, 2009). Head-body stunning induces heart fibrillation that prevents proper blood flow. This causes further cerebral hypoxia that deepens and extends the duration of unconsciousness induced by the head electrodes (Pleiter, 2005; Vogel *et al.*, 2011). While head-only electrical stunning is reversible, head-body stunning is generally irreversible, as the fibrillation often causes cardiac arrest (Lambooij and Spanjaard, 1982; Terlouw *et al.*, 2016a).

During and immediately following correct application of the current, due to the massive discharges in the brain, the muscles are in a tonic contracted state for several seconds; the animal extends the forelegs and flexes the hind legs (Croft, 1952; Warrington, 1974; Blumenfeld *et al.*, 2003). Subsequently, one or several clonic states follow, characterized by irregular jerking movements of the extremities and body (Croft, 1952; Warrington, 1974; Lambooij, 1982; Lambooij and Spanjaard, 1982; Velarde *et al.*, 2002; Blumenfeld *et al.*, 2009). Results on sheep suggested that, during the tonic phase and the first clonic phase, the animal was unconscious, representing a period of about 29 s (Croft, 1952; Velarde *et al.*, 2002). In the case of head-body electrical stunning, depending on the species and site of the electrodes, part of the current aiming at inducing heart fibrillation may pass

through the spinal cord. This has a paralysing effect and the tonic and clonic muscle contractions are less pronounced than following electrical head-only stunning (Wotton *et al.*, 1992). Therefore, the advantages of this method are not only a longer-lasting or irreversible unconscious state, but also a lesser degree of post-stun muscle contractions. The disadvantage is that the partially paralysing effect may mask possible signs of consciousness.

Hair, wool, feathers, bones, dirt, fat tissue and the outer layer of the skin have relatively high electrical resistance and may partly block the transfer of the current from the electrodes to the brain (Faes *et al.*, 1999; Velarde *et al.*, 2000; Grandin, 2019). The exact distribution of the electric field within the brain depends on the location of the electrodes and the characteristics of the animal (Terlouw *et al.*, 2016a). It is essential that sufficient electricity passes through the brain and that this occurs instantaneously (Lamboojij, 1982; Lamboojij and Spanjaard, 1982). As the resistance of the tissues diminishes once the current starts to flow (Kalinowsky, 1939; Wotton and O'Callaghan, 2002; Fish and Geddes, 2009), the initial voltage needed to reach the correct intensity instantaneously is higher than subsequently (Gregory, 2001). The administration of an electrical shock to the head, which does not induce immediate unconsciousness, is extremely painful (Impastato, 1954; Fish and Geddes, 2009). Once a current of sufficient intensity crosses the brain, the loss of consciousness occurs in 0.2 s (Kalinowsky, 1939; Liberson, 1948; Cook *et al.*, 1995); from that moment on, there is no longer a conscious perception of pain or fear signals. Taking into account the time that pain signals need to reach the cortex and the time needed for conscious processing, the maximal time allowance

to reach the correct current intensity is relatively short (Fig. 14.5).

Stunning with a gas mixture

Gas stunning is used for pigs and poultry. Normal air contains 21% O₂, 0.03% CO₂ and the remainder is N₂. The principle of gas stunning is to immerse animals in a gas mixture most often containing high concentrations of CO₂, the remainder being air. Pigs are lowered in a gondola into a pit, while poultry are placed on a conveyor belt entering a tunnel, both filled with the CO₂ mixture.

Proper regulation of the concentration of blood gases, CO₂ and O₂, is vital. Oxygen is an essential need for energy metabolism of the body, while CO₂ is metabolic waste that must be eliminated. In the alveoli of the lungs, the molecules move from higher towards lower concentrations. When the CO₂ concentration is higher in the air inhaled than in the blood, CO₂ is absorbed into the bloodstream. The CO₂ dissolves in the blood, thereby acidifying it. This acidification is detected by sensors called chemoreceptors (Teppema and Dahan, 2010). The chemoreceptors are stimulated by low O₂ and/or high CO₂ in the blood and transmit their information to respiratory centres in the medulla of the brainstem, allowing the immediate faster and deeper breathing response (Timmers *et al.*, 2003; Forster and Smith, 2010; Chang *et al.*, 2015). However, when an animal is immersed in a mixture rich in CO₂, the elimination of CO₂ is not possible even if respiration is faster or deeper. The acidification of the blood results in the acidification of the brain cells, occasioning the depression of brain activity, causing the loss of consciousness. Respiration slows down and finally stops due to dysfunction of

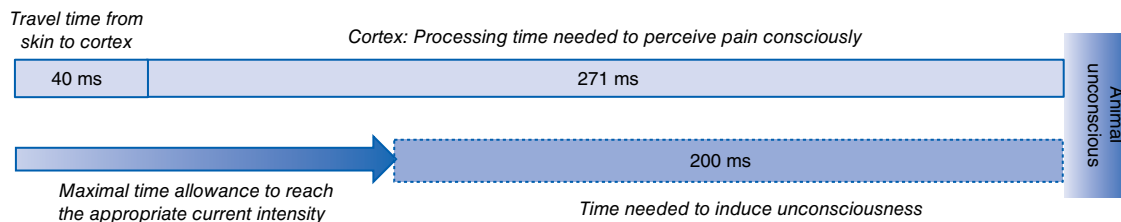


Fig. 14.5. Estimated time delays in the context of electrical stunning. The electricity causes a painful stimulus in the tissues beneath the electrodes, which the animal must not perceive consciously. The time needed for this stimulus to reach the cortex is unknown, but assuming a speed of 8 m/s (Box 14.3) and a travel distance of 30 cm in a pig, this could represent around 40 ms. Once a pain stimulus reaches the cortex, the processing time needed for conscious perception is on average 271 ms (Box 14.3). In this assumed case, the conscious pain perception starts after 311 ms. As 200 ms are needed to induce unconsciousness, maximal time allowance to reach sufficient current intensity would be 111 ms.

underlying nerve cells, resulting in death (Terlouw *et al.*, 2016a). In parallel, the heart rate increases initially, but subsequently slows and stops if the situation continues (Terlouw *et al.*, 2016a). The delay until loss of consciousness and induction of death are shorter with higher concentrations of CO₂ but this delay depends on the species (Conlee *et al.*, 2005). In pigs and birds, loss of brain responsiveness occurred 21 s after the start of immersion in 80% and 86% of CO₂ in air, respectively (Raj and Gregory, 1994; Raj *et al.*, 1997).

The disadvantage of gas stunning in terms of animal welfare is the relatively long delay until loss of consciousness, during which animals show reactions seemingly expressing aversion, such as avoidance behaviours and difficult breathing (Dodman, 1977; Forslid, 1987; Gerritzen *et al.*, 2004). In pigs, the respiratory changes occur within seconds of immersion in CO₂ (Forslid, 1987; Velarde *et al.*, 2007). Various studies have addressed the potential aversive nature of inhaling high CO₂ concentrations. Food-deprived pigs accepted to enter a box for a food reward when containing air, but not when it contained a mixture with 90% CO₂, indicating that high CO₂ concentrations are aversive, although another study found that in certain contexts aversion is limited (Raj and Gregory, 1995; Jongman *et al.*, 2000). The aversive nature was confirmed in humans, in whom CO₂ inhalation causes pain and a sensation of discomfort; high CO₂ concentrations even induced apnoea (Anton *et al.*, 1992; Brannan *et al.*, 2001; Terlouw *et al.*, 2016a).

During the immersion, animals often show convulsions (apparently involuntary muscle contractions). Some studies indicate that the muscle contractions take place only after the loss of consciousness, suggesting that these expressions are reflexes and not indicative of aversion (Forslid,

1987). Other studies showed the opposite (Velarde *et al.*, 2007; Rodríguez *et al.*, 2008). Overall, the occurrence of convulsions before, during or after the loss of consciousness seems to differ between studies, suggesting that their appearance may be context or animal dependent.

Some gas stunning systems are based on the use of inert gases, such as N₂ or argon (Raj *et al.*, 1997; Dalmau *et al.*, 2010; Llonch *et al.*, 2012). The anaesthetic principle of these mixtures is the lack of O₂ (Box 14.4). Depending on the study context, compared with CO₂, behavioural responses to inert gases are less (Gerritzen *et al.*, 2000; Sandilands *et al.*, 2011) or on the contrary more pronounced, especially if induction time is taken into account (Lambooij *et al.*, 1999; Gerritzen *et al.*, 2004).

Bleeding with or without prior stunning

Bleeding can be performed on an intact animal (religious slaughter), a dead animal (some cases of gas or electrical stunning) or an unconscious animal. The initial physiological effects of massive haemorrhage of a living animal are essentially related to the lack of oxygenation of the brain. In the non-stunned animal, the lack of O₂ in the brain following bleeding leads to a slowing of brain activity, causing a progressive decrease in the level of consciousness until the animal is unconscious (Box 14.4). If O₂ and glucose continue to be lacking, the cerebral nervous tissue is irreversibly damaged and the animal dies. The different structures of the brain do not have the same vulnerability to blood loss: for example, the blood circulation in the brainstem and thalamus is better preserved than in other parts of the brain (Mueller *et al.*, 1977). There is a reason for this: most vital functions are under the control of centres in the brainstem;

Box 14.4. The brain's needs

The brain has high glucose and oxygen needs but small storage capacities. In humans, the brain represents 2% of body weight, but uses 20% of total body O₂, 10–20% of the glucose and 15% of cardiac output (Zauner and Muizelaar, 1997). The amounts may be slightly lower in animals, but remain high. For example, the sheep brain uses 10% of body O₂ (Vernon, 2005).

When the brain lacks O₂, neurons can no longer produce energy and they progressively lose their

electrical charge. The lack of O₂ in the brain leads to further acidification of the cells, which also hampers normal functioning (Martoft *et al.*, 2003; Nordström *et al.*, 2012). Following the interruption of cerebral blood flow, brain activity stops after 12–72 s, depending on the experimental context and species, and energy reserves are exhausted after 1 min. Unconsciousness probably occurs before exhaustion of energy reserves (Terlouw *et al.*, 2016a).

consequently, vital functions such as breathing and maintenance of homeostasis are preserved as long as possible despite blood loss.

The effects of bleeding on consciousness in non-stunned animals vary between species. Sheep lose consciousness on average after about 14 s (range 10–20 s) (Schulze *et al.*, 1978; Devine *et al.*, 1986; Verhoeven *et al.*, 2015a). In chickens and turkeys, bleeding without stunning caused loss of consciousness between 12–202 s and 18–51 s, respectively (Terlouw *et al.*, 2016b). In cattle, the results vary even more. In calves of different ages, loss of consciousness or death occurred between 5–336 s following bleeding (Terlouw *et al.*, 2016a). Part of this large variability in cattle is due to the formation of occlusions at the ends of severed carotids in part of the animals, slowing exsanguination. In these animals, the vertebral arteries continue to irrigate the brain and the animal remains conscious (Gregory *et al.*, 2006). In certain cases of halal slaughter, the animal is stunned before or just after religious throat cutting to accelerate loss of consciousness (Farouk, 2013; Nakyinsige *et al.*, 2013).

Determining Insensibility, Unconsciousness and Death

Following stunning, a number of indicators allow assessment of the state of consciousness or unconsciousness of the animal (Verhoeven *et al.*, 2015b; Terlouw *et al.*, 2016a,b). These observable signs are indirectly associated with brain functions involved in consciousness, particularly the brainstem and/or the cerebral cortex. To ensure unconsciousness, indicators of consciousness must be absent and indicators of unconsciousness must be present (Table 14.2). During unconsciousness, the cortical structures are no longer functional, including those involved in the perception of pain (Box 14.2). In other words, the unconscious animal does not perceive pain. The relevance of the main indicators of consciousness, unconsciousness and death and their limitations are discussed.

Indicators of Consciousness and Unconsciousness

Standing posture and righting

In the slaughter context, the permanent loss of the standing posture is an indicator of the loss of consciousness. Following a correct mechanical or electrical stun, the loss of the standing posture is

immediate. During gas stunning and when bleeding animals without stunning, the loss of posture is progressive.

Postures and movements observed following penetrating captive bolt stunning depend on the extent and localization of the brain damage (Box 14.6). Experiments showed that small animals (cats, rats, rabbits) with damage involving only the thalamus but not the midbrain or pons are capable of standing and show spontaneous locomotion while keeping their balance in a near-normal manner (Magnus, 1925, 1926a,b; Siegel *et al.*, 1983; Musienko *et al.*, 2015). However, they lack spontaneous movement; an external stimulus is necessary to set them into motion (Takakusaki, 2017). No data are available for larger animals such as sheep or cattle with this type of brain damage; possibly, their weight makes effective standing more difficult, but it is probable that they show righting movements (Box 14.7). The degree of consciousness of animals with such damage depends on the presence of intact projections between the reticular formation and cortex (Fig. 14.1).

Damage reaching the midbrain or lower causes immediate loss of the standing posture. Immediately following effective penetrative captive bolt stunning, the animal lies down, often with extended limbs if it is on its side. This specific attitude is caused by dysfunction of motor pathways in the midbrain and pons (Bazett and Penfield, 1922; Pollock and Davis, 1930) (Fig. 14.6). The subsequent progressive relaxation of the muscles probably reflects the progression of impairments towards lower brainstem regions (medulla). The immediate collapse observed following electrical stunning is due to the seizure spreading through the subcortical structures and the brainstem (Terlouw *et al.*, 2016b). Gas stunning and bleeding without stunning induce gradually a loss of capacity to maintain the standing posture, probably due to a global progressive dysfunction of cortical and subcortical structures, including the brainstem: loss of posture is one of the first behavioural signs that overall brain activity has started to decrease (Mohan Raj and Gregory, 1990, 1994; Raj *et al.*, 1990; Gerritzen *et al.*, 2000; Gibson *et al.*, 2015a). At this stage, exposure to the gas needs to continue to make the slowing of brain activity more profound and widespread. During bleeding without stunning, some cattle regain the standing posture briefly, probably due to transient physiological adjustments partly restoring neurological function, before the final collapse (Gregory *et al.*, 2010; Bourguet *et al.*, 2011; Terlouw *et al.*, 2016a).

Table 14.2. Interpretation of indicators of consciousness and unconsciousness. Animals presenting one or more indicators of the first two categories (*Consciousness* and *Risk of consciousness or of return of consciousness*) must be immediately re-stunned.

Indicator	Anatomical interpretation	Comments	References
<i>Consciousness</i>			
Standing posture	Midbrain, pons, medulla functional	If the midbrain, pons, medulla are functional, while the thalamus and surrounding regions are extensively damaged, reflex standing is possible although the degree of consciousness of the animal may be altered (Fig. 14.1b). This situation is unlikely to occur in the slaughter context	Magnus, 1925, 1926; Pollock and Davis, 1927; Pollock and Davis, 1930; Halsey and Downie, 1966; Kao <i>et al.</i> , 2006; Musienko <i>et al.</i> , 2015
Coordinated head righting with or without body righting reflex	Midbrain, pons, medulla functional	A hoisted animal raising its head parallel to the floor with a stiff, hollow back presents a head righting reflex which is not acceptable following penetrating bolt stunning	Magnus, 1925, 1926; Pollock and Davis, 1927; Pollock and Davis, 1930; Siegel <i>et al.</i> , 1986; Grandin, 2002
Species-specific vocalization	Midbrain functional		Behbehani, 1995; Jürgens, 2009
Response to the threat test	The cortex, retina, optical nerve and motor system in the brainstem are sufficiently functional to produce a positive response	Should not be confused with a corneal reflex caused by air movement Caution is advised in the interpretation as unconscious patients in a vegetative state were reported to present a blink response to the threat test	Limon <i>et al.</i> , 2010; Verhoeven <i>et al.</i> , 2015b, 2016; Terlouw <i>et al.</i> , 2016b; Blumenfeld, 2009
<i>Risk of consciousness or of return of consciousness</i>			
Eye tracking	Relevant circuits in the midbrain and pons partly functional	Should not be confused with primitive orienting reflexes	Batini <i>et al.</i> , 1958
Repeated spontaneous blinking	Relevant circuits in the midbrain, pons, medulla and upper cervical cord partly functional		Van de Werf and Smit, 2008; Blumenfeld, 2009; Kaminer <i>et al.</i> , 2011; Terlouw <i>et al.</i> , 2015
Eyeball rotation and/or nystagmus	Relevant circuits in the midbrain and pons partly impaired creating an imbalance in the vestibulo-ocular system	Damage to the cerebellum may also cause nystagmus	Abadi, 2002; Strupp <i>et al.</i> , 2014
Incomplete head or body righting reflex	Relevant circuits in the midbrain, pons and/or medulla partly functional	Sheep may not hang completely straight. Certain reflex reactions to the manipulation of unconscious stunned or bled animals are normal	Magnus, 1925, 1926; Modianos and Pfaff, 1976; Musienko <i>et al.</i> , 2015; Terlouw <i>et al.</i> , 2015; Grandin, 2019
Presence of corneal reflex	Relevant circuit in the pons and medulla functional		Cruccu and Deuschl, 2000; Aramideh and Ongerboer de Visser, 2002

Continued

Table 14.2. Continued.

Indicator	Anatomical interpretation	Comments	References
Presence of rhythmic breathing	Relevant circuits in the pons and medulla functional		Ramirez <i>et al.</i> , 1998; St John, 2009; Smith <i>et al.</i> , 2013
<i>Unconsciousness or death</i>			
Instantaneous and permanent loss of standing posture without righting reflexes	Damage to the midbrain, pons and/or medulla	Specific, local lesions or impairments in the midbrain, pons and/or cerebellum may cause loss of standing posture with at least partial preservation of consciousness Loss of standing posture is not a predictor of the <i>duration</i> of unconsciousness Transection of medulla or upper spinal cord, by placing the stun gun (or puntilla) in the nape of the neck while orienting it towards the floor causes immediate collapse while the animal is <i>fully conscious</i>	Fulton <i>et al.</i> , 1930; Pollock and Davis, 1930; Halsey and Downie, 1966; Tidswell, 1987; Limon <i>et al.</i> , 2010; Musienko <i>et al.</i> , 2015
Absence of corneal reflex	Damage to the pons and/or medulla	Electrical stunning: may be a false absence due to tonic or clonic muscle contractions Direct bleeding: may be a false absence due to eye muscle contractions	Cruccu and Deuschl, 2000; Aramideh and Ongerboer de Visser, 2002; Terlouw <i>et al.</i> , 2016b
Absence of rhythmic breathing	Damage to medulla	Captive bolt (frontal shot): impairment of medulla is indicative of profound damage and therefore longer-lasting unconsciousness Electrical stunning: may be false absence due to muscle contractions interfering with respiratory muscles Transection of medulla or upper spinal cord, by placing the stun gun (or puntilla) in the nape of the neck while orienting it downwards causes respiratory arrest while the animal is <i>fully conscious</i>	Limon <i>et al.</i> , 2010; Smith <i>et al.</i> , 2013

Box 14.5. Following stunning, the state of the animal often evolves

Following stunning, the brain is generally not in a static but rather in a progressively changing state. Following application of the captive bolt, brain functions may be progressively lost, due to spreading brain haemorrhage, or may recover, for example if the bolt has caused a shock wave but little irreversible brain damage. Following head-only electrical stunning, normal

brain function progressively recovers. Heart fibrillation following head-body electrical stun often results in heart arrest and consequently death, but in some cases, the heart resumes normal functioning. Following immersion in CO₂, animals either die or progressively recover (Table 14.1). For these reasons, animals have to be monitored until the end of exsanguination.

Box 14.6. Brain control of posture and movement

Posture and movement involve several functions. Extensor and flexor muscles allow standing; they maintain an enduring and correctly balanced muscle tone, acting against the effect of gravity. Centres and pathways in the midbrain, pons and medulla control these functions. These structures assure further that the attitudes of different parts of the body change in a harmonized way; for example, if one part of the body changes, other parts assume a different attitude as well (Magnus, 1925, 1926a,b; Schepens and Drew, 2004; Takakusaki, 2017) (Box 14.7). These centres function automatically, that is, voluntary action is not needed.

Areas in the cortex are involved in initiating and controlling voluntary movement. These more complex

activities combine many input sources, such as visual information on the environment, the positions of the joints and muscles, the body state and needs, and memory (Patla, 1997; Beloozerova and Sirota, 2003). Although the brainstem pathways can independently organize gross motor control, the motor cortex is essential for the voluntary and fine movements. The basal ganglia, situated between the cortex and the brainstem, are important intermediate stations, necessary for smooth changes between movements (Purves *et al.*, 2004). The cerebellum plays a major role in the maintenance of posture and coordination of movements. Loss of the standing posture occurs with lesions at the level of the rostral midbrain.

Box 14.7. Relationships between posture, righting reflexes and balance

Righting functions assure that if, by its own active movements or by some outside force, the body of the animal is brought out of its normal posture, a series of reflexes are elicited so that it can reach or maintain its normal position.

Righting relative to gravity is controlled by labyrinthine information from the inner ear (in the temporal bone) and the vestibular nuclei (in the rostral medulla) and their interconnecting circuits. They allow putting the head correctly with respect to symmetry and gravity, even on an inclined surface.

Body and neck-righting reflexes consist of a relatively fixed chain of reflex movements: first, the head is brought into a normal position, subsequently the neck and the trunk. The automatic components of the righting reflex chain are generated in the brainstem; their voluntary control arises in the cortex (Magnus, 1925, 1926a,b; Pollock and Davis, 1930). Righting reflexes use labyrinthine information, but may exist without this. For example, moving the head of a labyrinthless animal

(i.e. one from which the labyrinth, or inner ear, has been removed experimentally), even passively (by an experimenter), stimulates proprioceptors of the neck muscles which in turn act on the legs (e.g. turning the head to the side causes extension of the limbs on the side to which the head is turned). The centres for these righting reflexes lie in the medulla. Righting reflexes also use tactile stimuli: pressure on one side of the body (as when an animal is lying down) stimulates righting of the head. Pressure on two sides of the body does not. The centres for these righting reflexes lie in the midbrain (Magnus, 1926b).

Control of posture and righting are integrated functions. They have different inputs, but share the output pathways. Similarly, balance results from the combined corrective movements and depends on the capacities of the animal to maintain the standing posture and to correct its posture by righting. Balance is less good or absent if the circuits involved in standing and righting do not work correctly.

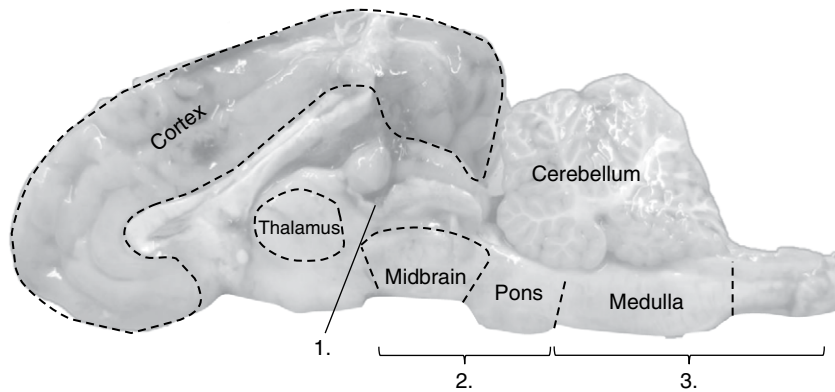


Fig. 14.6. Effects on standing and righting responses of different transections of the brainstem. These transections result from experimental surgical preparations and not from situations encountered in the slaughter context. 1. Animal capable of standing, locomotion when triggered, balance close to normal, righting reflex present. 2. No standing or locomotion, no righting; legs extended. 3. Animal flaccid but some reflex activity possible depending on context (Pollock and Davis, 1927; Ranson and Hinsey, 1929; Fulton *et al.*, 1930; Siegel *et al.*, 1986; Musienko *et al.*, 2015).

Permanent loss of the standing posture is closely associated with, but not identical to, loss of consciousness (Table 14.2): cell groups and pathways in the brainstem with a central role in maintenance of the standing posture and in righting reflexes are in close proximity to other brainstem cell groups and pathways, essential for the maintenance of consciousness. In the context of captive bolt stunning, loss of the standing posture indicates that the midbrain is injured; if this damage is widespread, the animal is unconscious. In the context of gas and electrical stunning, loss of the standing posture is a sign of widespread dysfunction of the brain, encompassing the midbrain.

Righting reflexes aim at bringing an animal into its normal posture (Box 14.7). Animals with lesions of the thalamus present righting reflexes (Magnus, 1925, 1926a,b; Pollock and Davis, 1930). Lesions of the midbrain or lower abolish coordinated righting reflexes (Magnus, 1925, 1926a,b) (Box 14.7). A complete oriented righting reflex following release from the stunning box involves the righting of the head, followed by righting of the trunk. The legs may be positioned and raise the trunk in a coordinated manner if the animal is physically capable (Magnus, 1926b). Coordinated, oriented righting reflexes must be absent following stunning because their presence indicates that the midbrain is not impaired; they are indicators of consciousness (Table 14.2).

After hoisting, an animal may present a head-righting reflex, raising its head parallel to the floor with a stiff, hollow back (Grandin, 2002) (Table 14.2). Following penetrating bolt stunning, such a head-righting reflex

on the slaughter line indicates that the brainstem was not sufficiently damaged and is not acceptable. Following religious slaughter without a stun, an animal that was bled correctly may present a stiff-hollow-back head-righting reflex on the slaughter line. In this case, the reflex is indicative of residual activity in the righting reflex circuit of an unconscious or dead animal (Terlouw *et al.*, 2015). However, in certain cases, the movement may be indicative of a risk of consciousness, particularly if the animal is not correctly bled. In this case, other signs of consciousness will be present (see Table 14.2 and below) and this situation is not acceptable.

The head, neck and trunk movements are inter-related (Boxes 14.6 and 14.7) and a passive change in the orientation of the head of animals with midbrain damage (e.g. an experimenter moves the head) may induce reflex leg movements (Bazett and Penfield, 1922; Pollock and Davis, 1930). The attitudes and movements of animals with midbrain damage depend further on whether they are lying down or suspended (Pollock and Davis, 1930). Following captive bolt stunning of cattle, hoisting or other forms of manipulation will change the position of the head with respect to the body (integrated in the medulla), and the animal loses its tactile information from the floor (integrated in the midbrain). This may explain certain reflex reactions of the legs or neck and head during manipulation or hoisting.

Leg movements may also result from residual nervous activity in pattern-generating centres in the brainstem and spinal cord, involved in the production of pattern movements, such as walking (Burke *et al.*, 2001;

Guertin, 2009; Frigon, 2012; Takakusaki, 2017). This explains some of the paddling movements that cattle present on the slaughter line following captive bolt stunning or following bleeding without stunning. The functioning of these generators is independent of consciousness; the simple presence of these movements does not indicate consciousness (Terlouw *et al.*, 2015).

The loss of the standing posture or the presence of oriented righting reflexes may be difficult to evaluate when animals are physically restrained, for example fowl suspended on the rail, or animals maintained in restraining boxes or V-restrainers. Righting becomes very rudimentary (and more difficult to evaluate) if the animal cannot stand. Transection of the brainstem below the pons, or of the spinal cord without damaging the midbrain, which may occur if the stun gun is fired in the nape of the neck while oriented downwards, results in immediate collapse, while the animal is fully conscious as its upper brainstem remained intact (Figs 14.1b and 14.6; Table 14.2) (Fulton *et al.*, 1930). Finally, immediate collapse is not a reliable predictor of the durability of the unconscious state, for which other signs are more appropriate (see Table 14.2 and below).

Eye movements and eye reflexes

Presence of spontaneous eye or eyelid movements or the absence of certain eye reflexes are often used to

evaluate unconsciousness in the slaughter context. If the muscles of the eyes are passive, the eyeballs are centrally placed in the orbit (Box 14.8). Following an effective mechanical stun, the animal closes its eyes and immediately opens them. Following a gas stun, the eyes are generally open with eyelids and eyeballs immobile. After an effective electrical stun, the eyes are initially closed due to the tonic contraction of the muscles caused by the current, then reopened (Grandin, 2019).

The corneal reflex is tested by lightly touching the cornea: if the reflex is present, the eyelid closes. The reflex involves the transmission of sensory information to the pons eliciting a motor response via the reticular formation (Fig. 14.8) (Cruccu and Deuschl, 2000; Aramideh and Ongerboer de Visser, 2002). In the slaughter context, if the corneal reflex is absent, there is a large probability that the disruption is associated with a wider dysfunction, comprising part of the reticular formation and/or thalamus, and thus with a state of unconsciousness (Cruccu *et al.*, 1997; Laureys, 2005). Hence, unconscious animals may show a corneal reflex, but an animal that does not is unconscious. In calves slaughtered without stunning, the corneal reflex was lost 1 min or more after the loss of consciousness (Lambooj *et al.*, 2012; Verhoeven *et al.*, 2016). For this reason, the absence of the corneal

Box 14.8. Brain control of eye movements

Eyes are highly specialized organs that collect important information. They function partly automatically controlled by several cell groups in the midbrain, pons and medulla (Fig. 14.7). Visual information is shared with other brain structures, such as the cortex, thalamus and basal ganglia.

In larger mammals, cell groups in the midbrain, the lower pons, the medulla and upper cervical cord control eyelid opening and closure (Schmidtke and Büttner-Evener, 1992; Bour *et al.*, 2002; Van de Werf and Smit, 2008). Groups of nerve cells in the midbrain receive information from the optic nerve and control the muscles involved in pupillary constriction and lens accommodation to adjust for the amount of light that falls on the retina and to obtain a clear image (Figs 14.7 and 14.8).

In their neutral (relaxed) position, the eyeballs are centrally placed in the orbit. Eyes are capable of locking on to an object and maintaining a clear vision of it, even when the object is moving, a function

called tracking. The eyes can also fixate on an object even when the head or the entire animal is moving. To take into account head and body position and movements, they exchange information with the circuits involved in locomotion and posture (Boxes 14.6 and 14.7). Six muscles are attached to the eyeballs to allow movement; several cell groups in the cerebellum, midbrain and the pons (Fig. 14.7) control them (Tehovnik *et al.*, 2000; Enderle, 2006). Cell groups in midbrain and pons ensure that eyes are maintained in their position; otherwise, they would drift back into their neutral position.

Other cell groups in the midbrain and in the pons are involved in the coordination of eye movements. They receive information from cortical and subcortical areas. Figure 14.7 illustrates the complexity of this interconnected system. A local lesion in the midbrain or pons interrupting the network may create an imbalance, leading to unusual eye positions or movements such as eyeball rotation or nystagmus.

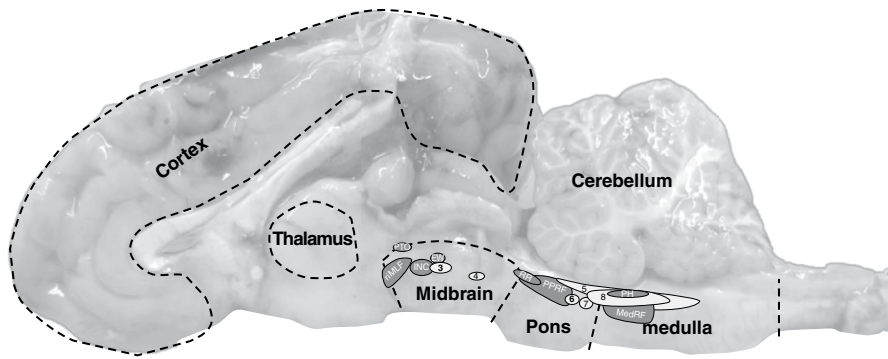


Fig. 14.7. Major cell groups involved in the control of eyelid and eyeball movements (Bhidayasiri *et al.*, 2000; Purves *et al.*, 2008). Cranial nuclei (light grey): oculomotor (3: horizontal and vertical eye movements, raising of the eyelid, eyeball retraction); trochlear (4: vertical eye movements), principal sensory trigeminal (5: sensory perception of the cornea and other areas of the face), abducens (6: horizontal eye movements, eyeball retraction), facial (7: eyelid closure, in larger animals also eyelid opening) and vestibular (8: smooth eye pursuit) nuclei. Other brainstem nuclei (dark grey): pretectal olivary and Edinger-Westphal nuclei (PTO and EW: pupillary constriction and lens accommodation), rostral Raphe group (RR: maintenance of eye position), the interstitial nucleus of cajal and prepositus hypoglossus (INC and PH: gaze holding), rostral interstitial nucleus of the medial longitudinal fasciculus and paramedian pontine reticular formation (riMLF and PPRF: control of saccades) and the medullary reticular formation (MedRF; organization of eye movements). For simplicity, connections between the cell groups are not depicted. Impairment of the nuclei or the connecting circuits leads to imbalance of the controlling system, which may be expressed in uncontrolled eye movements.

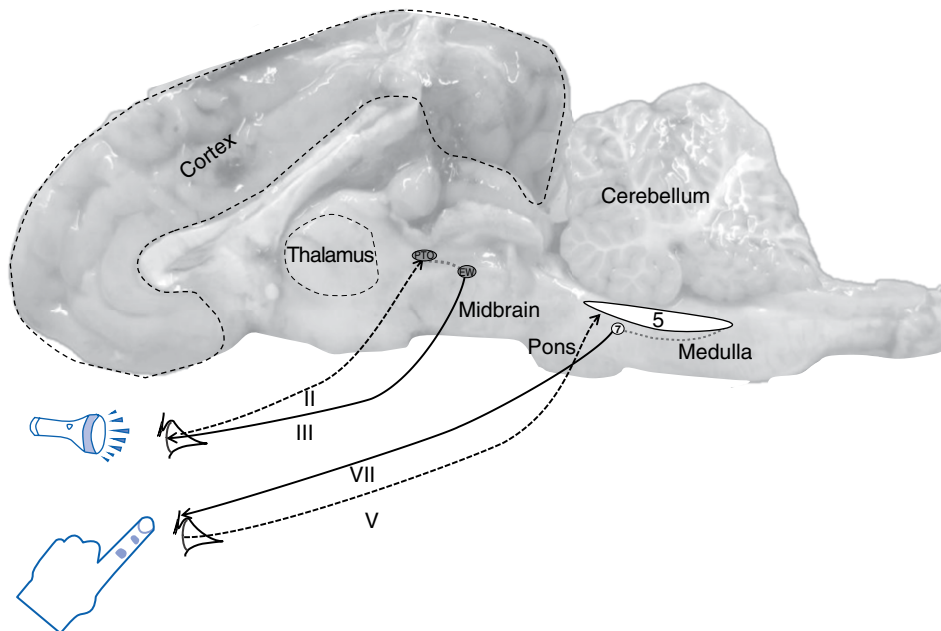


Fig. 14.8. Simplified representation of circuits involved in the pupillary and corneal reflex responses (Ongerboer de Visser and Moffie, 1979; Davidson *et al.*, 2000; Kozicz *et al.*, 2010). The pupillary reflex involves sensory information from the optic nerve (II) travelling via the pretectal olivary (PTO) nucleus, an interneuron, the Edinger-Westphal (EW) nucleus and the oculomotor nerve (III) to the sphincter muscle of the pupil, which contracts in response to increased light. The corneal reflex involves sensory information travelling via the trigeminal nerve (V), the trigeminal nucleus (5) and interneurons to the facial nucleus (7); the latter sending a signal via the facial nerve (VII) to the muscle of the eyelid allowing eyelid closure. Sensory and motor nerves are represented by dashed and continuous lines, respectively. Interneurons are represented by dotted lines.

reflex is a reliable indicator of unconsciousness at slaughter.

The palpebral reflex is tested by a light touch of the eyelid and the eyelash reflex by lightly brushing the eyelashes. The responses are also eyelid closure, and at least for the palpebral reflex the neural circuit is largely similar to that of the corneal reflex. During slaughter without stunning, the eyelash reflex is generally lost after the loss of corneal reflex, suggesting that it is more resistant to the effects of anoxia (Terlouw *et al.*, 2016b). The exact procedure of these tests and their interpretation in terms of unconsciousness need further studies.

The nictitating membrane or third eyelid covers the eyeball in many birds, reptiles, amphibians and fish, and in some mammals such as rabbits, in response to touching the cornea. It is a passive reaction caused by the stimulation of the cornea and the active retraction of the eyeball by muscles and controlled by centres in the midbrain, pons and medulla (Berthier *et al.*, 1983; Evinger *et al.*, 1995). Following electrical stunning, the external eyelids close but the third eyelid remains open. In birds, the reflex can be tested even if external eyelids are closed as the movement of the membrane can be seen or felt underneath the eyelids (Erasmus *et al.*, 2010).

The above reflexes cannot be tested correctly in the case of strong eye muscle contraction. After electrical stunning, the tonic state and the subsequent vigorous clonic movements may interfere with the eyelid response, or make it difficult to carry out the test or to interpret the results correctly (Grandin, 2019). Particularly in non-stunned cattle, eye muscles may present tonic contraction immediately after the start of the bleeding and the response may be absent while the animal is conscious. Finally, the corneal reflex test is difficult to interpret when the animal has blood in the eyes.

Persistent eyeball rotation is indicative of local impairments in the brainstem. For example, a lesion of specific nerves in the midbrain (oculomotor nerve) or lower pons (abducens nerve) causes the eye to turn inward or outward and downward, respectively. Eyeball rotation may be observed following captive bolt stunning; it may be full (iris hardly visible) or partial (half of the iris still visible) (Atkinson *et al.*, 2013). It indicates a risk, as 50% of the cattle presenting full rotation also showed other signs of potential consciousness (Gouveia *et al.*, 2009; Atkinson *et al.*, 2013). The sign is particularly relevant for captive bolt stunning. During eyeball rotation, it may be impossible to touch the cornea to carry out the corneal reflex

and, in addition, the eye muscle contraction could interfere with the response (Terlouw *et al.*, 2016b).

The pupillary reflex is the contraction of the pupil when suddenly exposed to light (Box 14.8; Fig. 14.8). The presence of fixed dilated pupils may be a useful indicator of a correct stun for all techniques and for bleeding of non-stunned animals (Table 14.2). It may be difficult to use immediately following electrical stun before bleeding, due to time constraints and muscle contractions. The pupillary reflex test necessitates further that the retina and optic nerve are functional (Box 14.8). The pupillary reflex is not valid if blood covers the cornea, or if blood loss reduces the functioning of the optic nerve (Lee *et al.*, 2008).

Spontaneous blinking is initiated by reduced tear film thickness as well as a spontaneous blink generator and involves circuits in the brainstem and upper spinal cord (Box 14.8). Voluntary blinking involves, in addition, circuits in the cortex (Van de Werf and Smit, 2008; Kaminer *et al.*, 2011; Xiao *et al.*, 2015). The sign is relevant for all methods of stunning and for bleeding of non-stunned animals, but its absence does not necessarily indicate unconsciousness and its presence not necessarily consciousness (Table 14.2). Spontaneous blinking has been observed in vegetative patients and unconscious penetrative bolt-stunned bulls (Blumenfeld, 2009; Terlouw *et al.*, 2015). Their presence in a stunned unconscious animal indicates that certain structures of the brainstem, possibly related to the blink generator, are still functional (Schmidtke and Bittner Ennever, 1992; Van de Werf and Smit, 2008).

Eye tracking involves different structures in the brainstem and in the cortex (Box 14.8). It does not occur in vegetative patients and the return of sustained and consistent eye tracking movements or fixation is one of the first signs of a return of consciousness in these patients (Blumenfeld, 2009). However, in the unconscious state primitive orienting reflexes may occur, consisting of eyes and head turning towards a visual or auditory stimulus, presumably mediated by intact brainstem circuits (Majerus *et al.*, 2005; Blumenfeld, 2009). In the slaughter context, repeated eye tracking (Box 14.8) indicates consciousness or a risk of return of consciousness, but its absence does not necessarily indicate unconsciousness (Table 14.2). The sign is relevant for all methods of stunning and for bleeding of non-stunned animals.

Nystagmus is a vertical, horizontal or torsional rapid oscillation of the eyeball due to repeated contractions of muscles of the eye. Several neural circuits working in concert localized in the cerebellum, midbrain and pons, including the reticular formation, are involved in the

coordination of eye movements (Box 14.8). Damage to one or more of these circuits may create an imbalance in their functioning and lead to nystagmus (Hüfner *et al.*, 2007). The direction of the nystagmus depends on the localization of the impairment of the circuits. In down-beat nystagmus the fast component of the oscillation is downward; it is generally caused by lesions in the cerebellum or lower pons (Hüfner *et al.*, 2007). In the context of slaughter, nystagmus is an indicator with low discriminatory power: when present, the brainstem is damaged but possibly not sufficiently to obtain a profound and long-lasting state of unconsciousness (Gregory *et al.*, 2007; Terlouw *et al.*, 2015). The sign is particularly relevant for captive bolt stunning (Table 14.2).

For the threat test, a finger or the hand is moved rapidly towards the eye of the animal and the presence of a withdrawal reaction (unrestrained animal) or a blinking response is checked. The test may be insufficiently sensitive, as a positive response could be obtained in unconscious humans (Blumenfeld, 2009). In sheep and cattle in the slaughter context, the presence of a reaction to the threat test was associated with other indicators of consciousness (Limon *et al.*, 2010; Verhoeven *et al.*, 2015b, 2016). The test is only valid if the eye is functional, if there is sufficient light and the corneal surface is not covered. The presence of a response to the threat test is indicative of a risk of consciousness or of a return to consciousness. The absence of a reaction does not prove that the animal is unconscious (Majerus *et al.*, 2005) (Table 14.2).

Rhythmic breathing

An unconscious animal breathes if only the mid-brain is impaired, but the caudal pons and rostral medulla remained intact (Figs 14.1 and 14.8).

However, the absence of breathing is an indicator of unconsciousness; it indicates that the cell groups in the pons and medulla controlling respiration no longer function (Box 14.9; Fig. 14.8). Following captive bolt stunning, the absence of breathing indicates that there is damage to the deep structures of the brainstem and that there is a high probability that the unconsciousness will be durable. A successful electrical stun causes immediate respiratory arrest, because the seizure spreads to medulla, blocking normal function of the cell groups controlling respiration (Massey *et al.*, 2014; Box 14.9). However, following the electrical stun, breathing may change or stop for other reasons. Specifically, tonic and clonic muscle contractions following application of the current may hamper proper functioning of the respiratory muscles (James *et al.*, 1991). Following head-body stunning, the current flowing between the head and heart could also affect neurons in the spinal cord and/or respiratory muscles, which may cause respiratory arrest. Consequently, following an electrical stun, breathing is often difficult to evaluate and to interpret. However, the presence of breathing indicates consciousness (Table 14.2).

During bleeding without stunning or gas stunning, breathing ceases progressively. Bleeding of the non-stunned animal progressively causes a lack of O₂ of the nerve cells in the brainstem controlling breathing, which stop functioning (Terlouw *et al.*, 2016a). Due to the immersion in the gas mixture, these same nerve cells progressively lack O₂ and become acid, with the same consequence (Martoft *et al.*, 2003). The absence of breathing after gas stunning indicates that unconsciousness was achieved, but does not give information of the durability of the unconsciousness. If animals are

Box 14.9. Brain control of respiration

Several cell groups in the pons and medulla control respiration. Cell groups in the rostral medulla are responsible for inspiration and expiration, respectively. Other cell groups, located in the rostral and caudal pons and in the medulla, are in charge of the oscillation between inspiration and expiration (Feldman *et al.*, 2013; Smith *et al.*, 2013). A lesion at the level of rostral medulla causes irregular and abnormal breathing, over time often leading to respiratory failure (Ramirez *et al.*, 1998; McKay *et al.*, 2005; Tan *et al.*, 2008) (Fig. 14.9). Lesions between the most caudal

respiratory groups at the midlevel of the medulla, and the third cervical vertebra, lead to immediate respiratory arrest, without altering consciousness (Parvizi and Damasio, 2003; St John, 2009) (Fig. 14.9).

The integration of breathing with many other activities, such as movement, eating and drinking, and vocalization, sniffing and swallowing, takes place in the pons (Smith *et al.*, 2013). Voluntary breathing, controlled by regions in the cortex, may bypass or override the brainstem mechanisms controlling automatic breathing (McKay *et al.*, 2003).

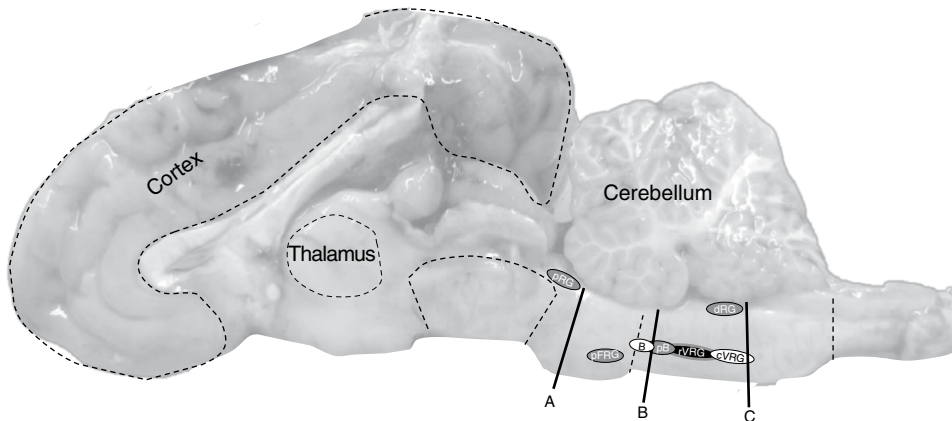


Fig. 14.9. Major cell groups involved in respiration (Smith *et al.*, 2013): pRG (pontine respiratory group: inspiratory–expiratory phase transition), pFRG (parafacial respiratory group: central chemosensory function), B (Bötzing complex: expiration), pB (preBötzing complex: pattern generator), rVRG (rostral ventral respiratory group: inspiration), cVRG (caudal ventral respiratory group: expiration), dVRG (dorsal respiratory group: integration of sensory inputs related to breathing). Cell groups indicated in black, white and grey indicate inspiratory, expiratory and other (integrative) functions, respectively. Experimental transections at or rostral to level A do not influence breathing. Transections between A and B cause slow but regular breathing with a sustained hold of the breath at peak inspiration. The pB is both necessary and sufficient for spontaneous respiration. Therefore, transections between B and C cause irregular, abnormal breathing, and gasping, ultimately leading to respiratory arrest. Lesions between C and the third cervical vertebra cause immediate respiratory arrest (Box 14.9).

still alive following the release from the CO₂ mixture, they may resume respiration, which is indicative of a return of consciousness.

Thus, the absence of breathing is a reliable indicator of unconsciousness for mechanical (frontal shot) and gas stunning and the return of breathing for the return of consciousness in electrically stunned animals. However, transection of the medulla or spinal cord above the third cervical vertebra stops breathing, while the animal remains fully conscious (Table 14.2).

Vocalization

Vocalizations refer to species-specific sounds produced by the animal. A vocalization following the stun may be reflex vocalization, expressing pain or fear, and involves only the midbrain, or voluntary communication with conspecifics, involving the midbrain and the cortex (Warriss *et al.*, 1994; Grandin, 1998). In either case, species-specific vocalization is indicative of consciousness (Box 14.10; Table 14.2). In addition, if the vocalization expresses pain, the animal is sensitive, which also indicates consciousness. Guttural sounds should not be confused

with vocalization; they may be secondary to breathing or gasping (see above).

Reaction to pain

The principle of nociceptive tests is to induce a noxious stimulus on the body or the head of the animal, for example a pinch (comb, ear tips or nasal septum), a skin prick with a hypodermic needle, or spraying with hot water (McKinstry and Anil, 2004; Limon *et al.*, 2010; Parotat *et al.*, 2015; Verhoeven *et al.*, 2015b).

Withdrawal of the stimulated body part is considered a positive reaction but the interpretation is difficult, because a nociceptive reflex response is difficult to distinguish from a conscious withdrawal response to perceived pain (Box 14.11). Properly stunned cattle may show a reflex response to exsanguination, involving a circuit through the spinal cord but not the brain; hence it is not a sign of consciousness. This type of reflex responses persisted 3 min after cessation of breathing (Terlouw *et al.*, 2015). Reflex withdrawal of the head exists also, possibly explaining the response to an ear pinch in pharmacologically anaesthetized sheep

Box 14.10. Brain control of vocalization

In general, animals produce two types of sound and a specific cell group in the caudal midbrain (periaqueductal grey) is essential for both. Elementary vocalizations associated with pain, fear or rage are mediated by a network inside this cell group, controlled by other brain areas to ensure that vocalizations are adapted to the context. For example, threatening calls are

produced when in the presence of a subordinate, but not a dominant conspecific (Behbehani, 1995). More complex forms of communication arise in various regions in the cortex, which project to this midbrain cell group (Holstege, 1989; Behbehani, 1995; Jürgens, 2009). Vocalization is coordinated with respiratory activity (Zhang *et al.*, 1995).

Box 14.11. Automatic nociceptive responses

The nociceptive reflex arc is a neural circuit that allows a rapid withdrawal of a limb when it is in contact with a noxious stimulus, even before the brain translates the signal into pain. This circuit involves a nociceptor carrying the message to the spinal cord, a short connecting neuron (interneuron) in the spinal cord and a motor nerve from the interneuron to the muscles in the limb. There is no intervention of the brain and the response is involuntary. In the conscious individual, the brain only subsequently interprets the stimulus in terms of pain.

A nociceptive reflex arc also allows the reflex withdrawal of the head in response to a noxious stimulus. The message is transmitted to cell groups in the pons (Manni *et al.*, 1975; Abrahams *et al.*, 1993; Serrao *et al.*, 2003). The motor neurons responsible for the retraction of the head are located in the cervical vertebrae. This circuit appears to involve several neurons, but it does not involve the brain cortex and the response is therefore also involuntary.

showing an EEG indicative of unconsciousness (Verhoeven *et al.*, 2015b) (Box 14.11).

Another difficulty is that the strength, location and/or type of the nociceptive stimulus seem to influence the likelihood of a response. After stunning and sticking, pigs presenting a corneal and pupillary reflex responded also to a hot-water spray as a nociceptive stimulus, but only one-third responded to a nasal septum pinch, another nociceptive stimulus (Parotat *et al.*, 2015). Similarly, immediately following a neck cut of non-stunned sheep, the withdrawal response to an ear pinch was lost, while breathing and the corneal reflex were still present and the EEG indicated the presence of consciousness (Verhoeven *et al.*, 2015b). These results suggest that, in the slaughter context, certain nociceptive stimuli may not be strong enough to evoke a reaction, or possibly that certain animals, although conscious, are physically unable to respond. Therefore, a pronounced reaction to a relatively moderate nociceptive stimulus, such as a pinch, may be indicative of consciousness. The presence of a reaction to a strong nociceptive stimulus may involve a reflex arc and is not necessarily indicative of con-

sciousness. The absence of a response is not a reliable indicator of unconsciousness. Reactions to nociceptive stimuli must be associated with other clinical signs to help interpret them.

Determining unconsciousness

Studies describing the neurological bases of the clinical signs discussed above generally do not describe the associated state of consciousness, though there are a few exceptions (Mettler, 1965; Halsey and Downie, 1966; Takakushi, 2017). Hence, knowledge of the exact relationships between clinical signs related to brainstem function and state of consciousness is still incomplete, mainly due to the complexity of the subject (Majerus *et al.*, 2005).

In the context of slaughter, it is essential to use several indicators to verify unconsciousness (Table 14.2). The standing position, righting reflexes and vocalization indicate consciousness. Following captive bolt or gas stunning, the loss of the standing posture, the absence of eye movements and ocular reflexes and of rhythmic breathing indicate widespread dysfunction of the midbrain, pons and

Box 14.12. Definition and diagnosis of death

Most countries define the death of an individual in terms of brain death: the irreversible and permanent cessation of the functioning of brain structures responsible for vital functions like breathing, and thermal and cardiovascular regulation (Laureys, 2005). Most studies find that brain activity is irreversibly lost after 5 min of interruption of brain circulation (Stiegler *et al.*, 2012; Terlouw *et al.*, 2016b).

Early clinical signs of brain death involve the absence of signs of life: persistent cardiac and

respiratory arrest, the absence of all brainstem reflexes, total absence of consciousness and total absence of spontaneous motor activity. Reflex movements of the trunk and limbs related to a residual nerve activity in the spinal cord may persist (Laureys, 2005; Terlouw *et al.*, 2015). In the human context, confirmatory testing may be used to confirm the absence of electrical activity, blood flow and metabolic activity (Laureys, 2005).

medulla and consequently unconsciousness. In the case of electrical stunning, the loss of the standing posture and the induction of a tonic state of at least 10 s indicate that sufficient electricity has crossed the brain and that the animal is unconscious, although consciousness may return if the animal is not bled rapidly (Croft, 1952; Warrington, 1974). A return of consciousness is accompanied by the return of the corneal reflex and of rhythmic breathing for all stunning techniques (Terlouw *et al.*, 2016b).

Determining death

In the slaughter context, death is generally caused by a lack of O₂ supply to the brain, often associated with a lack of nutrient supply resulting from cardiac and/or respiratory arrest or exsanguination. It may also be caused by brain damage in the case of a mechanical stun, especially in small animals.

It is difficult to diagnose death formally in the slaughter context (Box 14.12). In practical terms, dressing or scalding is carried out after verification of the absence of certain signs of life; the animal is not breathing, shows no brainstem reflexes and, in addition, is bled properly. If these three points are confirmed, in the context of the abattoir and at this stage of slaughter, the loss of vital functions is irreversible because the animal is completely bled and can therefore be considered dead (Terlouw *et al.*, 2016b).

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15 The Importance of Good Pre-slaughter Handling to Improve Meat Quality in Cattle, Pigs, Sheep and Poultry

TEMPLE GRANDIN*

Department of Animal Science, Colorado State University, USA

Summary

Careful low-stress handling at the slaughter plant can help maintain meat quality. Poor handling practices shortly before stunning can increase problems with tough meat in cattle and pale soft exudative (watery) (PSE) meat in pigs. There is a basic principle of the effects of the stress of handling and transport on meat quality. Short-term stresses such as electric prod use in the stunning race cause lower pH in the meat and increase lactate and glucose levels (Edwards *et al.*, 2010). Longer-term stresses such as long transport times raise pH and increase dark cutting. To explain it simply, short-term stresses a few minutes before stunning tend to make meat tougher and light in colour. Longer-term stresses darken meat colour and reduce shelf life. Both PSE and dark cutting or dark firm dry (DFD) meat are severe quality defects.

There are exceptions to the short-term versus long-term stress rule, but in general, this principle is true. To explain it in an easy to understand manner, dark cutters occur when the muscle glycogen is depleted and lactic acid can no longer be produced. This causes the muscle pH to rise. A good analogy is a car running out of fuel. When the glycogen runs out, the pH will rise and meat color will darken. There are many factors that can contribute to the 'fuel' running out. Dark cutting may be caused by a combination of long transit times, fluctuating hot and cold temperatures, nutrition, hormone implant programs, animal genetics, bulls fighting

and mounting in the lairage, and other factors (Ponnampalam *et al.*, 2017). In both livestock and poultry, careful handling will reduce the percentage of bruised animals.

Learning Objectives

- Understand factors that can cause meat quality problems during handling and transport.
- Learn the importance of low-stress handling to maintain meat quality.
- How on-farm conditions have an effect on meat quality.
- Bruises can be reduced in all species with careful handling.

The Importance of Maintaining High Meat Quality

Both PSE and DFD meat are severe quality problems (Przbylski and Hopkins, 2016). **Figure 15.1** shows both normal and dark cutting beef. PSE pork has poor water binding and it has greater cooking losses (**Fig. 15.2**). Dark cutting beef and lamb is darker and has a shorter shelf life in the grocery store (Adzitey and Nurul, 2011). Consumers generally prefer high-quality pork, beef and lamb (Viljoen *et al.*, 2002). Handling practices at the abattoir can have a significant effect on meat quality (Grandin, 2015; Faucitano, 2018).

* Email: cheryl.miller@colostate.edu

Detrimental Effects of Short-term Stress

Jamming in the race and electric prod use within 5 min prior to stunning increased blood lactate levels in pigs and had a detrimental effect on pork quality (Edwards *et al.*, 2010; Vermeulen *et al.* 2015a,b; Oliveira *et al.*, 2018). Faucitano (2018) reported that improving handling reduces PSE and skin damage. Hambrecht *et al.* (2005a,b) found that some of the most detrimental effects of poor handling occurred close to the time of stunning. Lactate levels can be easily measured at bleeding as an indicator of the quality of handling (Edwards *et al.*, 2010; Rocha *et al.*, 2016). Squealing shortly before stunning is associated with both physiological measures of stress and poor pork quality (Warriss *et al.*, 1994) (see Chapter 12).

When pigs are handled carefully, lactate levels will be in the single-digit range of 4–6 mM (Benjamin *et al.*, 2001; Edwards *et al.*, 2010). Other studies have shown that lactate levels can range from 4.4 mM to 31 mM depending in the quality of handling (Warriss *et al.*, 1994; Hambrecht *et al.*, 2004,

2005a,b). Lactate can be easily measured with a handheld meter (Burfeind and Heuwieser, 2012). Rapid chilling will reduce PSE, but it will not prevent poor-quality pork caused by high pre-slaughter stress (Hambrechet *et al.*, 2004).

Similar results have been found in cattle. Repeated shocking of cattle with an electric prod shortly before stunning resulted in tougher meat (Warner *et al.*, 2007). Cattle with high lactate levels at bleeding had tougher meat (Gruber *et al.*, 2010). Meat tenderness was measured with the Warner Bratzler shear test.

For assessment of stress shortly before slaughter, there are two easy-to-use temperature measurements. Pigs at risk for poor-quality PSE meat had higher body temperatures (Vermeulen *et al.*, 2015a,b). Body temperatures can be measured in live pigs shortly before stunning with infrared thermography (Rocha *et al.*, 2016). Continuous scoring of handling practices should be used to maintain low-stress handling. Either the animal welfare officer or the quality assurance manager should monitor handling practices. Scoring of handling is covered in Chapter 12. Low levels of electric prod use, animals falling down, jamming or vocalizing in the stunning area will help preserve meat quality.

To preserve meat quality, it is essential that the producer deliver to the slaughter plant animals that are easy to handle. Weak or lame animals that are less willing to move may be more likely to be handled roughly with excessive electric prod use. Highly excitable animals or aggressive animals are also difficult to handle. Many welfare issues that occur at abattoirs are due to conditions outside the plant.



Fig. 15.1. Dark cutting (DFD) beef is shown on the right hand side and normal red beef is shown on the left. Dark cutting beef is a severe quality defect.

Good Lairage Practices

Low-stress handling is difficult if the livestock refuse to move easily. Pigs should be rested in the



Fig. 15.2. The picture on the right shows pale soft exudative (PSE) pork and the picture on the left shows normal pork. Pale soft pork has poor water-binding capacity and has a low pH. (Photo from www.fao.org.)

lairage pens (stockyard) for 1–3 h before stunning. This will make them easier to handle. Research clearly shows that resting reduces PSE (Milligan *et al.*, 1998; Perez *et al.*, 2002; Warriss, 2003). The time of resting is calculated as the total time the pigs are in the lairage holding pen. They should have a minimum of 1 h of undisturbed rest. Overnight resting provides no advantages. In some cases, too many hours spent in the lairage may result in stiff difficult-to-move animals. Stress was reduced if pigs were held in a lairage for under 4 h. Perez *et al.* (2002) concluded that both a failure to rest pigs in the lairage or an excessively long period in the yards without food is detrimental to pork quality. Cattle should have a short period to settle down after truck uploading. In some countries, long lairage periods are required. Unfortunately, there may be some situations where this could cause dark cutters.

Handling Bulls

Ideally, bulls should be kept in farm penmate groups throughout transport and during lairage at the plant. Mixing bulls from different pens will cause fighting and mounting, because the animals have to establish a new dominance order. Agonistic (fighting) behaviour between bulls that are mixed increases dark cutting (Price and Tennessen, 1981). Bulls have a tendency to have more dark cutters than steers. Mounting behaviour, and the increased physical exertion associated with it, increases the incidence of dark cutting (Tarrant, 1989). Many abattoirs that slaughter bulls construct a roof with steel bars over each pen in the lairage. This prevents bulls from mounting if they have to be mixed with strange bulls. Devices that prevent mixed bulls from mounting will reduce dark cutters (Bartos *et al.*, 1988).

Handling Practices on the Farm Will Affect Handling Ease at the Abattoir

An animal's experience with handling on the farm will have an effect on its behaviour at the slaughter plant. Pigs will differentiate between a person walking in the alley and a person walking through their pens. Pigs that have never experienced people walking through their pens on the farm may be more difficult to handle at the plant (Grandin, 2014, 2015). They may be more likely to pile up and squeal when people attempt to move them. Producers should walk through the fattening (finishing)

pens every day to train pigs to move quietly away from people walking through them. Research clearly shows that previous experiences with handling at the farm will make pigs easier to handle in the future (Abbot *et al.* 1997; Geverink *et al.*, 1998; Krebs and McGlone, 2009). Pigs that move easily will be less likely to be subjected to poor handling practices such as excessive electric prod use, pile-ups, jamming in races and squealing.

In cattle, on-farm handling practices can also have an effect on behaviour at the plant. Cattle that have never been moved by a person on foot can be difficult and dangerous to handle by a person walking on the ground (Grandin, 2015). This is more likely to be a problem with extensively raised cattle that are handled by cowboys on horseback. A person on a horse and a person on the ground look totally different. When cattle have become accustomed to the person on the horse, it is perceived as safe and familiar. The sudden appearance of a person on the ground is perceived as novel and frightening. This can greatly increase the animal's flight zone (see Chapter 6). This may also contribute to meat quality problems.

Pork Quality and Stunning Method

One reason why some pork abattoirs have switched from electrical stunning to CO₂ is to improve pork quality. The biggest problems associated with electrical stunning are bone fractures and ecchymosis (blood spots in the pork) (Channon *et al.*, 2003a,b; Marcon *et al.*, 2019). Fractured vertebrae can damage the loins. From a welfare perspective, fractures are a non-issue because the pig is rendered instantly unconscious. There is also some evidence that electrical stunning may increase PSE and cooking losses. This is especially a problem if long application times of 19 s are used (Channon *et al.*, 2003a,b). Short electrical stunning times of 4 s or less reduced problems with PSE.

During years of consulting, the author has learned how to greatly reduce problems with ecchymosis and bone fractures associated with electrical stunning. The following are recommendations to preserve pork quality.

- Do not energize the tongs until they are pressed firmly against the animal.
- Do not double stun.
- Do not slide the tongs during the stun. This is likely to cause the muscles to contract more than

once. This may increase the occurrence of fractures or ecchymosis.

- Keep the wiring connections and switches dry. All electrical equipment must be protected from water when the plant is cleaned. Store the tongs in a dry location. If possible, mount the stunner power unit in a separate utility room. Water in the wiring may increase electrical fluctuations and increase ecchymosis. Electrical current fluctuations may cause the muscles to contract more than once.
- Periodic replacement of tong wiring switches and connectors may reduce ecchymosis. Carbon deposits on electrical switch contacts may cause current fluctuations.
- Animals must be wetted, but electrical components such as switches must be kept dry.
- Frequently clean the electrodes that contact the animal.

Practical experience in many pork abattoirs by the author indicates that the meat quality difference between CO₂ and electrical stunning are greatly reduced by careful management of electrical stunning. Economics may not justify the use of CO₂ when it is compared with well-managed electrical stunning. Electrical stunning requires continuous attention to the details of the procedure. Some good reviews are in Grandin (1986) (see also Chapter 14).

Genetic Effects on Meat Quality

Pigs and cattle with a more excitable temperament may have poorer meat quality. In cattle, the animals with a more excitable temperament may have more dark cutters and meat quality problems (Voisinet *et al.*, 1997; King *et al.*, 2006; Café *et al.*, 2010; Hall *et al.*, 2011; Ponnampalom *et al.*, 2017; Della Rosa *et al.*, 2018). High death losses and increased PSE can occur in pigs that are homozygous for the porcine stress syndrome (PSS) halothane gene (Murray and Johnson, 1998). Fortunately, in many modern pig populations, this gene has been greatly reduced through selective breeding (Ritter *et al.*, 2009). There are still some populations of pigs with the halothane gene. It can be very detrimental to pork quality because the pigs may have more PSE. Pigs with the stress gene may quiver all over, lie down and become non-ambulatory. Sometimes their skin will have a red splotching area. To cool the pig, wet the floor around it. Spraying cold water directly on the pig may kill it.

Porcine Stress Gene Genetics

There are some older pig populations that may have been deliberately bred to have the halothane gene (named because of the adverse effects noticed under halothane anaesthesia), because it is associated with lean low-fat pork. The halothane gene is a classical Mendelian trait. For a pig to exhibit the PSS condition with high death losses, it has to inherit the halothane gene from both the sire and the dam. This creates a homozygous positive animal. The carrier (heterozygote) pig is created by inheritance of only one PSS gene from either one of the parents. The heterozygote animal will be less likely to have increased death losses. Its tendency to have PSE meat may be greater than pigs completely free of the halothane gene (Band *et al.*, 2005). A pig completely free of the halothane gene is homozygous negative. If a sire and dam that are carriers (heterozygotes) are mated, some but not all of the piglets will be homozygous positive for PSS.

Leg Conformation Problems and Lameness (Difficulty Walking)

Indiscriminate breeding for meat traits may be associated with poor leg conformation (Grandin, 2015). Pigs and cattle with poor leg conformation may have difficulty walking and be lame. Lame animals are more difficult to handle, which may lead to more electric prod use and rough handling. Producers should be encouraged to select both cattle and pigs with correct feet and legs (Le *et al.*, 2015a,b) (Fig. 15.3).

Lameness can be caused by other factors, such as poorly designed dairy freestalls (cubicles) and poorly bedded housing (Fulwider *et al.*, 2007; Grandin, 2015) (see Chapter 16 for lameness scoring methods). Another factor is housing cattle for long periods on bare concrete (Wagner *et al.*, 2016). Producers who deliver high percentages of lame animals to the abattoir should work to reduce lameness. There are many different causes of lameness and most of them originate at the farm. The first step in reducing lameness is to measure it and work with producers (Cook *et al.*, 2015; Grandin, 2017). The author has observed that cattle with swollen knee joints are more likely to lie in an abnormal position. Normal cattle will tuck both front legs under their bodies when they are lying down in sternal recumbency (lying on their brisket). If one of the front legs is sore, the animal will

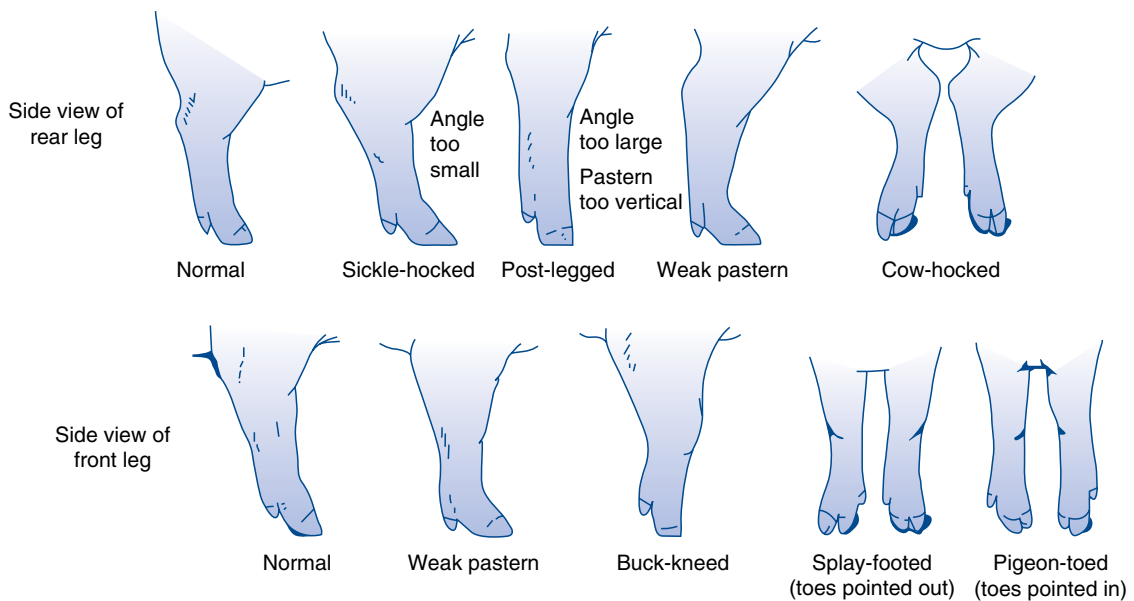


Fig. 15.3. Leg conformation chart. Diagrams of common poor conformation of the feet and legs of cattle, pigs and other livestock. Poor leg and hoof structure is a major cause of lameness (difficulty in walking). Breeders should select animals with the normal correct hoof and lower leg angle. An animal's hoof should point straight forward. The two diagrams on the bottom show poor conformation with toes pointed either in or out.

lie down and extend the leg straight out. The other front leg will be tucked under the body. Figure 15.4 shows a scoring chart for eroded knee joints in fattened feedlot cattle.

Factors that may be contributing to joint damage and lameness in livestock include:

1. Heavier weights at a younger age.
2. Leg conformation problems associated with indiscriminate genetic selection for carcass traits. In the late 1980s and early 1990s the pork industry had serious problems with lame pigs due to poor leg and ankle conformation. The author has observed that problems with downed non-ambulatory pigs were greatly reduced when pork producers stopped using a boar genetic line with poor legs. To prevent lameness, the Angus Association in the USA now has guidelines for leg conformation. Vollmar (2016) reported that cattle originating from ranches in northern USA were more likely to have the crooked-class hoof defects compared with cattle from Texas. This is possibly due to the more intensive breeding programmes at the larger northern ranches.
3. Feeding diets with excessive levels of concentrates such as grain. The animals may be being pushed too hard with high concentrate ratios.

4. Feeding young cattle for long periods on concrete slats. Wagner (2016) found that cattle housed on bare concrete slats had increased swollen knee joints compared with slats covered with rubber. The author observed that young 180 kg (400 lb) cattle housed for 100 days or less on bare concrete slats had knee joints with normal appearance, but similar cattle housed for longer periods on concrete slabs had leg problems. These cattle were fed a high grain diet. It appears that the length of time housed on the concrete slats is a factor. More mature heavy (539 kg) cattle placed on concrete slats were free of adverse effects (Earley *et al.*, 2017). This may be due to the cattle being more mature and fed more roughage. Elmore *et al.* (2015) also reported that rubber mats reduced joint swelling. Reducing the number of days that cattle are housed on slats will reduce joint swelling and leg abnormalities.

Cardiac Weakness, Liver Abscesses, Lung Lesions and Other On-farm Factors That May Affect Meat Quality

During my observations at slaughter plants, there are more and more welfare and meat quality prob-

Fed Cattle Knee Joint Score

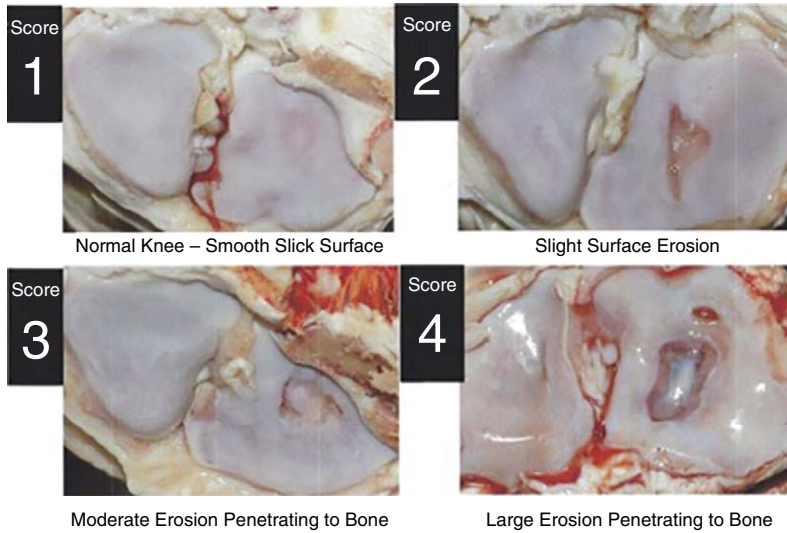


Fig. 15.4. Cattle knee joint scoring chart developed by Dr Scott Crain. A score of 1 is normal and a score of 4 is severe.

lems that will have to be corrected at the farm. These issues may cause death losses, more difficult handling or lower meat quality. To solve these problems will require changes in either production or breeding practices. A complete review of all the causes is beyond the scope of this book. However, it is important to be aware that many meat quality and livestock handling issues must be addressed at the farm. These issues may require changes in genetic selection, feeding or housing.

Poultry breeders have known for years that fast-growing broilers would often die from ‘flip over’ disease. Birds bred for meat have a higher susceptibility to cardiac arrhythmia problems (Gesek *et al.*, 2016). The livestock industry needs to avoid repeating some of these same mistakes. Research clearly shows that some heavy chickens have a severe meat quality problem called woody breast or white striping (Permentier *et al.*, 2015; Kuttapan *et al.*, 2016, 2017; Tijare *et al.*, 2016). Muscle can grow so rapidly that the circulatory system cannot keep up. In extreme cases, an area of necrosis will form in the middle of a poultry muscle (Velleman, 2015). In pigs, animals with reduced cardiac functions were more likely to die during transport (Zurbrigg *et al.*, 2017, 2019).

In beef cattle, some animals living at very high altitudes have cardiac problems. Some are more

resistant to the hypoxic effects of high altitudes than others. This condition is heritable (Will *et al.*, 1975; Newman *et al.*, 2015). Beef cattle bred to have superior carcass traits may have more difficulty living at high altitudes. Unfortunately, US ranchers are starting to observe cardiac problems in cattle that were originally only seen at high altitudes. Heart issues are occurring at much lower elevations (Neary *et al.*, 2015). It is possible that indiscriminate breeding selection for larger cattle and improved carcass traits has contributed to this problem. Genomic analysis found a possible weak association between growth and pulmonary arterial pressure (PAP) test of high-altitude sickness (Cockrum *et al.*, 2019). Heavy Angus steers with increased levels of adiposity (fat) were at increased risk of heart failure during finishing (fattening) (Neary *et al.*, 2015). Researchers at Kansas State University have described a new condition in beef cattle called fatigued cattle syndrome (Thomson *et al.*, 2015). It is most likely to occur in very large grain-fed cattle when they are subjected to physical exertion. Cattle that become non-ambulatory have high lactic acid levels (Thomson *et al.*, 2015). This is similar to fatigued pigs. This is extremely detrimental to both meat quality and animal welfare.

Liver Abscesses and Lung Lesions

Amachawadi and Nagaraja (2015) reported that 10–20% of fed beef cattle had liver abscesses. The problem was worse in grain-fed Holstein cattle (Amachawadi and Nagaraja, 2015). Holsteins with edible livers had higher carcass weights (Herrick *et al.*, 2018). McCoy *et al.* (2017) found that fed steers with severe liver abscesses had tougher meat and a reduction in carcass weights (Brown and Lawrence, 2010). Researchers in New Zealand found similar problems with an increased incidence of liver abscesses in pastured bulls. Meat inspection reports from 137,675 bulls indicated that dairy breed bulls had 10.3% abscessed livers and the beef breeds had only 4.7% (Trotter, 2016). Both studies illustrate that there is a genetic effect on the likelihood that an animal will get liver abscesses.

There may be a great variation in the percentage of cattle having liver abscesses. Groups of cattle may have a range of 0% to 70% (Reinhardt and Hubbert, 2015). This illustrates that feeding practices and other on-farm factors are associated with increased liver abscesses. Mild to moderate liver abscesses had a minimal effect on cattle performance (Davis *et al.*, 2007). Baier (2019) found that liver abscesses had no significant effect on measures of stress. Most liver abscess scoring systems do not differentiate between severe liver abscesses that adhere to the body wall and ones that do not. Research is needed to determine the effects of abscesses that cause adhesions. Trim loss from adhesions can destroy large amounts of meat.

Some groups of pigs will have a high percentage of lung lesions. Scollo *et al.* (2017) found that there was a strong relationship between certain farms and lung lesions observed at slaughter. Observations in the USA indicate that 10–15% may have lung lesions that adhere to the body wall. Lung lesions can greatly increase pork quality problems and downgraded carcasses (Permentier *et al.*, 2015; Karabasil *et al.*, 2017).

Effects of Growth Promoters and Hormones on Meat Quality, Handling and Death Losses

An animal's biology can be overloaded either by overzealous genetic selection for production traits or by administering too many growth or milk production promoters. Unless it is used very carefully, the hormone rBST, which is used for increasing

milk production, has caused problems in dairy cows. The cow may have increased difficulty maintaining her body condition and suffer more illness from mastitis (Kronfeld, 1994, 2000; Collier *et al.*, 2001). Problems with rBST may be closely related, with higher doses causing more problems. Cows given a high dose of 30.9 mg tended to have more days open and re-breeding required more artificial insemination (AI) services (Endman *et al.*, 1990).

Beta agonists (zilpaterol and ractopamine) increase muscle mass (Scamlin *et al.*, 2009). These products are not hormones or antibiotics. They may also make meat tougher (Shook *et al.*, 2009; Merez-Murillo *et al.*, 2016). The author and other people who work in slaughter plants have observed that cattle fed high doses of beta agonists are sometimes lame and stiff when they arrive (Grandin, 2015). This problem is more likely to occur during hot weather. Hagenmaier *et al.* (2017) also reported increased lameness in feedlot cattle during unloading at the abattoir during hot weather. Physical exertion and muscle fatigue during handling and transport may make it worse. Frese *et al.* (2016) reported that running 563 kg heavy fed steers for 1540 m raised physiological indicators of stress compared with walking them. Observations in the field indicate that problems are more likely to occur during hot weather over 32°C (90°F) on the day of slaughter (Grandin, 2015). Higher doses tend to worsen the detrimental effects. When pigs were fed a high dose of ractopamine, they were more difficult to handle (Marchant-Forde *et al.*, 2003; Ritter *et al.*, 2017). Aggression between pigs also increased in pigs fed high doses (> 10 mg) of ractopamine (Poletto *et al.*, 2008). During hot weather, death losses in cattle may be increased (Montgomery *et al.*, 2008; Longeragan *et al.*, 2014). Zilpaterol may also increase cardiac problems in cattle (Neary *et al.*, 2018). Pigs fed 20 mg ractopamine/kg were more likely to become stressed if they were handled roughly (James *et al.*, 2013). An increase in downed non-ambulatory pigs was related to the dose. A dose of 5 mg/kg had no effect and a dose of 7.5 mg/kg, fed for 28 days, increased downed fatigued pigs (Peterson *et al.*, 2015). Another study showed that ractopamine fed at a dose of 10 mg for 28 days increased epinephrine levels and had only minor effects on handling (Puls *et al.*, 2014). One study showed that heat stress may be increased in sheep fed beta agonists (Marcias-Cruz *et al.*, 2010). Another study done with zilpaterol showed minor heat stress effects

(Boyd *et al.*, 2015); 78% of the cattle had red hides and the temperature during the beta agonist feeding period was high, but it dropped below 32°C (90°F) on the day of slaughter. In the USA, zilpaterol has a 3-day withdrawal period prior to slaughter. The cattle in this study had an extra (fourth) day of withdrawal prior to slaughter. There is a possibility that this may have reduced the detrimental effects during handling and transport.

There is also evidence that high doses of ractopamine may be associated with hoof cracking in pigs (Poletto *et al.*, 2009). Feeding zilpaterol increased abnormal lateral lying posture in 31% of the cattle (Tucker *et al.*, 2015). Cattle fed a combination of a high-starch diet of potato waste and high doses of zilpaterol had sloughing off of the outer hoof shell during hot weather (Huffstutter and Polansek, 2013). Most problems were associated with either a combination of high doses or hot temperatures greater than 32°C (90°F), either shortly before or on the day of slaughter. In cattle and pigs, problems with both animal welfare and handling associated with beta agonists were associated with higher doses and longer periods of time on the additive. Baszczak *et al.* (2006) found that feeding ractopamine to cattle at a dose of 200 mg/day for 28 days had little effect. A review of the literature in pigs also indicated that higher doses cause more problems (Ritter *et al.*, 2017). To prevent problems with beta agonists, high doses must be avoided. Reports from veterinarians in the field indicate that feedlots can make their records appear to have low doses. This form of cheating is done by inputting into the computer that the animal will eat a smaller amount of feed than it actually does.

Synthetic male hormone ear implants containing trenbolone acetate can increase dark cutters if given at excessive doses (Scanga *et al.*, 1998). The author has observed that high doses can also cause feedlot heifers to have a masculine appearance.

Methods to Reduce Bruises in Livestock

The first step is to determine if bruises are happening within the abattoir or outside it. Bruises that originate from a problem inside the plant will usually occur on livestock from many different sources and they will be fresh. Exact ageing of bruises is difficult but fresh bruises on the day of slaughter will be bright red. Bruises that are 48 h old may be yellow or yellow/red (Hamdy *et al.*, 1957; McCausland and Dougherty, 1978; Strappini *et al.*,

2009). Old injuries that are several weeks or months old may have yellow discoloration (Grandin, 2015). In broiler chickens, bruises can be distinguished between recent and old. Chicken bruises that are over 24 h old will be greenish (Northcutt and Rowland, 2000). Fresh poultry bruises will be red.

Good record keeping is essential to document origin of bruises

To determine the origin of bruises (Boxes 15.1, 15.2), careful records should be kept of the location of bruises and the origin of the livestock. To reduce bruises in the abattoir, the first step is to find and prevent the bruises that are occurring inside the plant. The next step is to find bruises that are associated with certain truckers or farms. Research clearly shows that certain truckers or farms are associated with higher levels of either bruises or death losses (Gonzales *et al.*, 2012).

One of the most effective ways to reduce bruises and other losses is to hold transporters and producers economically accountable (Grandin, 1981, 2015). When people have to pay for bruises, they will work to reduce them.

Solving Bruise and Injury Problems in Poultry

Bruised legs

The author has observed that rough shackling is a major cause of bruised drumsticks. The people doing the shackling squeeze the legs too hard when they put the birds on the shackles. An understaffed shackle line where people have to hurry is one cause of bruised legs (Grandin, 2015).

Bruised chicken breasts

There are two major causes of bruised chicken breasts. One cause is jamming birds too quickly through the small opening in the top of the coop. The other results from machine catching systems when birds are jammed against the coop door by a conveyor that is out of alignment.

Smashed heads

This injury is most likely to occur when drawer systems are used for transporting chickens,

Box 15.1. Common causes of fresh bruises in the abattoir and during transport

- **Stun box door** – The door strikes the back of the animal due to either poorly designed controls or operation carelessness. One study showed that the door often hit cattle (Munoz *et al.*, 2012). Bruising can still occur after stunning and prior to bleeding (Meischke and Horder, 1976).
- **Rough livestock handling** – Poor handling methods can cause animals to fall down, jump on each other or get trampled. Cattle handled roughly had more bruises (Grandin, 1981; Weeks *et al.*, 2002; Mendonca *et al.*, 2016).
- **Sharp edges on equipment** – Edges with a small diameter are more likely to cause bruises (Fig. 15.5). Bruises caused by an equipment problem inside the abattoir will often be at the same location on animals from many different sources.
- **Overloaded trucks** – Transporters should follow truck loading guidelines. Overloaded trucks may have more bruised cattle and dead pigs (Ritter *et al.*, 2006, 2009; Schwartzkopf-Genswein and Grandin, 2014). Sheep are less likely to slip or fall during transport if they have adequate space (Jones *et al.*, 2010). If an animal goes down and it is stepped on by other animals, it may have severe bruising over large areas of the carcass.
- **Poor driving** – Sudden stops and starts may throw animals off-balance and increase bruising. Good driving practices will reduce bruises (Tarrant *et al.*, 1992; Schwartzkopf-Genswein and Grandin, 2014).
- **Truck compartments too low** – If tall cattle are getting more back bruises, the height of the truck compartments may be too low (Fig. 15.6). One study showed that tall Holstein steers had more bruises than shorter beef breed cattle (Lee *et al.*, 2017). This is likely due to taller animals hitting the underside of the decks.
- **Grabbing sheep by the wool** – Lifting sheep by the wool will cause severe bruises. Managers must train employees never to grab sheep by the wool.
- **Sticks with nails in them** – Poking animals with sticks with nails on the end will damage the hides and cause bruises. Pointed objects for driving animals should be prohibited.
- **Slippery floors** – Slick floors in trucks, races, lairage pens and other areas can cause animals to fall.
- **Worn-out metal** – Animals rubbing against metal equipment can wear holes through pipes and sheet metal. These worn areas may have extremely sharp edges that can tear hides and cause bruises.

Box 15.2. Common causes of older bruises

Older bruises will no longer be red. They will be darker and have areas with yellowish mucus. The author has observed that yellowish mucus can still be present several months after an injury.

- **Auctions and livestock markets** – Livestock that pass through markets will usually have more bruises than animals sold to the abattoir directly from the farm of origin (Cockram and Lee, 1991; Hoffman *et al.*, 1998; Weeks *et al.*, 2002).
- **Fighting and mounting** – Mixing strange animals at markets can increase bruises.
- **Number of times handled and transported** – Livestock that are handled multiple times or loaded and unloaded many times often have more bruises.
- **Hail damage** – Cattle hit by hail will often have multiple small bruises.
- **Swinging gates into animals** – Animals can become bruised if gates are swung at them in an attempt to stop animal movement down an alley. The worst bruises occur if the animal gets stuck between the end of a gate and a fence.
- **Tieback gates** – Gates in markets and lairages should be equipped with tiebacks to prevent them from accidentally swinging out into groups of approaching livestock.

where the birds are put in trays that are slid into rack-like dresser drawers. Drawer systems that have been redesigned so that there is a gap between the stop of the drawer and the rack

frame seldom have this problem. This gap prevents the head of a chicken from being smashed when the drawer full of chickens is slid back into the rack.



Fig. 15.5. Edges with a small diameter such as steel angle irons are more likely to cause bruises than larger rounded surfaces. Steel T shapes and angles are not recommended for lairage construction.



Fig. 15.6. Back bruise on a tall animal that hit the underside of a low truck compartment. Cattle can be severely bruised and the hide may have no visible damage. (Photo courtesy of Helen Kline, Colorado State University.)

Broken wings

The number one cause of this problem is rough handling during catching. Chickens should *never* be picked up by a single wing. Measuring the percentage of broken wings is a sensitive indicator of how people are handling the birds. Broken wings can also occur in systems where birds have to be

removed from the coop through a small door. When individual coops are used, the best ones have a small door for loading the birds and the entire top opens to remove the birds for shackling at the plant. [Figure 15.7](#) shows both broken and bruised wings on broiler chickens.

There is a big difference in the percentage of chickens with broken wings between the best and worst plants. Some ethicists are hesitant to state an acceptable level of broken wings, because that translates into thousands of birds with broken wings. The author has observed that when numerical standards were introduced for measuring broken wings, they were greatly reduced. In the USA before measurement started, 5–6% of the birds had broken wings. With the present data, the maximum acceptable level would be 1% and plants with 3% are clearly not acceptable.

Broken legs

In spent hens, weak bones are a major contributor to fractures (Webster, 2004). Old hens have high percentages of keel bone fractures due to osteoporosis (Sherwin *et al.*, 2010; Wilkins *et al.*, 2011). In broiler chickens, rough handling is a major cause. There is much controversy among welfare specialists on the correct way to pick up chickens during catching. Some specialists state that they should never be picked up by a single leg. In some countries, this is the normal catching method. The author has observed one-legged catching where the number of birds injured was very low. The coops were brought into the barn close to the catcher. The catcher never walked more than 3 m to load the chickens into the coops (Grandin, 2015).

Recommendations on Poultry Catching Methods

It is the author's opinion that instead of arguing over whether poultry are hand-caught or machine-caught, caught by one leg or two legs, or lifted by the entire body, the best approach is to measure injuries and deaths.

These percentages will measure the outcome of poor handling. Broken wings should be counted when the feathers are on, to prevent counting breakage from the feather-removal picking machine. The broken wing score should include both breaks and discolorations.



Fig. 15.7. Wing damage on broiler chickens. The top row shows broken wings after the feathers have been removed. When assessing broken wings at the abattoir, scoring the birds with the feathers on avoids confusion between damage from feather removal equipment and damage from handling. When chickens are hung on the line, a broken wing hangs straight down. The bottom two photos show bruised wings that are not broken.

Trouble-shooting Problems

Sometimes a problem, such as high percentages of downed non-ambulatory pigs, is caused by a combination of factors. At one large slaughter plant, correcting three different contributing factors almost eliminated non-ambulatory pigs. The three factors that brought about improvements were: (i) instructing producers to walk through the finishing fattening pens to get the pigs accustomed to quietly moving away when people walked through them (Grandin, 2015); (ii) reducing or eliminating ractopamine use; and (iii) stopping using genetic lines with either the PSS halothane gene or poor leg conformation.

Conclusions

Conditions in the slaughter plant and conditions outside the slaughter plant can both contribute to meat quality issues. The first step is to determine if the problem is occurring in the abattoir or outside it. The next step is to correct in-plant problems such as poor handling, lack of lairage rest time for pigs or mounting behaviour in bulls. Problems that are usually caused by on-farm factors are (i) animals that are difficult to handle; (ii) lameness; (iii) high death losses; (iv) bruises; or (v) tough meat caused by feed additives. These issues must be corrected at the farm. Use measurements with numerical scoring to determine the origin of the problem.

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16 The Use of Abattoir Data to Provide Information on the Welfare of Livestock and Poultry on the Farm and During Transport

TEMPLE GRANDIN^{1*} AND MICHAEL COCKRAM^{2†}

¹*Department of Animal Science, Colorado State University, USA;* ²*Sir James Dunn Animal Welfare Centre, Atlantic Veterinary College, University of Prince Edward Island, Canada*

Summary

A range of conditions that may compromise animal welfare can be assessed at the abattoir. Injuries associated with handling and transport and pathology associated with conditions that were present on the farm can be identified (Grandin, 2017). Some examples are fitness for transport, lameness, bruises, wounds, skin lesions on poultry and death losses. It can be more efficient to undertake some types of welfare assessments on animals after they have been transported to slaughter at a limited number of locations than to attempt to visit the large number of farms that supply each abattoir. Studies have shown that many welfare problems can be assessed at the slaughter plant (EFSA Panels, 2011; Harley *et al.*, 2012a,b; Llonch *et al.*, 2015; Souza *et al.*, 2018). It is also easier to identify some conditions post-mortem than in live animals. The collection of slaughter plant data is an integral part of many welfare assessment schemes, such as Welfare Quality (2009) and commercial (private) programs that are outlined in Grandin (2012, 2015), Lundmark *et al.* (2018) and Vogeler *et al.* (2019). Data is collected from routine ante-mortem and post-mortem inspections of carcasses and viscera (internal organs) for gross pathological changes. Although this data collection is undertaken for food safety reasons, it

provides relevant animal welfare information. However, there are some issues with the quality and nature of these data that need to be considered when they are used for welfare assessment. The provision of feedback to producers on welfare issues identified at slaughter remains an underutilized tool for reducing on-farm health and welfare issues. Fully integrated systems, especially in the poultry and pig industries, for additional data collection by specific assessors and provision of producer feedback have been developed. Providing feedback to producers is more difficult in segmented marketing chains where an animal passes through auctions or dealers.

Learning Objectives

- Learn the on-farm animal welfare problems that can be easily identified at the abattoir.
- Understand the limitations of these assessments.
- Provide information for implementing these assessments.
- Introduce the scientific studies on assessment methods.

Introduction

The first section of this chapter will cover how to get started in assessing animal welfare issues at the

* Email: cheryl.miller@colostate.edu

† Email: mcockram@upei.ca

abattoir that occur during transport or on the farm. The second section will cover an in-depth review of the literature on welfare assessments at the abattoir. In the next section, the most important indicators for a practical commercial programme are outlined. There will also be a discussion on the limitations of in-abattoir welfare audits. For example, they cannot be used to determine the influence of some aspects of the type of housing that the animals were raised in or to determine if analgesics or anaesthetics were used during painful surgical procedures.

Tables 16.1, 16.2 and 16.3 contain an overview of conditions that can be easily assessed at the abattoir.

Different Types of Measurement Systems and Choosing the Most Suitable Scoring Tools

There are many different published scoring systems available for scoring condition of animals on the farm. Some of the measures that have good inter-observer reliability are lameness (difficulty walking), sores and lesions, feather/coat condition, animal or bird cleanliness and neglected injuries (Gibbons *et al.*, 2012; Llonch *et al.*, 2015) (Tables 16.1 and 16.2). Scoring tools are also used for assessing internal indicators of poor health such as liver abscesses, lung lesions and stomach ulcers (Hardstaff *et al.*, 2012; Leruste *et al.*, 2012) (Table 16.3).

A scoring tool has good inter-observer reliability if several different people use the tool and the results agree most of the time. Agreement can never be perfect but it should be the same 70–90% of the time. Some of the best scoring tools have photographs to show normal and varying degrees of a problem ranging from normal to severe (Fig. 16.1). To help improve inter-observer reliability, auditors, government inspectors and abattoir quality assurance people should be trained to always keep the scorecard with them. The scorecard can either be a plastic laminated card or kept on a smart phone. When assessors are well trained, they can achieve substantial agreement (Leruste *et al.*, 2012).

Use of Critical Control Points (CCPs)

As used by Grandin (2019), a critical control point is a factor in an audit or assessment that is extremely important. If a factor that is a CCP is failed, there would be a severe welfare problem.

Some welfare issues that can be detected at the abattoir are more serious than others. It is the first author's opinion that lameness is an example of a CCP. Lameness is in pain (Flower *et al.*, 2008). An example of a less serious welfare indicator may be a few small scratches on a pig. The principle of CCPs comes from food safety. In Hazard Analysis Critical Control Points (HACCPs), the CCP is a point, step or procedure in a process where hazards can be controlled or reduced to an acceptable level (critical limit) (Hulebak and Schlosser, 2002). A basic HACCP programme measures the really important welfare indicators. In the next section of this chapter, the CCPs for each species will be covered.

Some of the most important variables that should be assessed at the abattoir are as follows:

- dead animals, all species;
- non-ambulatory downers;
- lameness in livestock;
- broken wings (poultry);
- bruises and fractures;
- skin lesions, both livestock and poultry;
- dirty livestock or poultry;
- poor body condition;
- obvious neglected health problems;
- liver abscesses in cattle;
- lung lesions in livestock;
- hernias in pigs; and
- udder problems in dairy animals.

Commercial versus research assessment tools

There is a difference between a scoring system that is used in a research study and a system used under commercial conditions. Commercial systems often have to be simpler. A more complex system can provide more graduations of severity, but it will be harder to train people to use it accurately under commercial conditions. A good commercial system will usually have fewer categories than the most sensitive research tools.

There is much discussion in the scientific literature and in the industry on the number of categories a scoring tool should have. An assessment tool assessing animal welfare during stunning and handling with simple yes/no scoring is described in Chapter 11 (Grandin, 1998, 2000, 2005, 2010). Each animal is either stunned correctly or is not stunned correctly with single application of the

Table 16.1. Overview of conditions associated with either poor fitness for transport or poor handling and transport practices.

Welfare problem	Comments	References
Dead on arrival	The prevalence and where possible the reasons should be recorded	Murray and Johnson (1998); Averos <i>et al.</i> (2008); Caffrey <i>et al.</i> (2017); Di Martino <i>et al.</i> (2017); Cockram and Dulal (2018)
Dead in lairage	The prevalence and where possible the reasons should be recorded	Knowles <i>et al.</i> (1994); Fitzgerald <i>et al.</i> (2009); Knezacek <i>et al.</i> (2010)
Moribund (near death)	The prevalence and where possible the reasons should be recorded	Stafford <i>et al.</i> (2001)
Recumbent/non-ambulatory (not able to walk)	Where possible determine whether the condition was associated with injury or fatigue. The cause should be recorded	Ritter <i>et al.</i> (2009); Thomson <i>et al.</i> (2015)
Heat stress	Identified using clinical signs (open-mouth breathing). Cattle with open mouth breathing at rest have severe heat stress	Mader <i>et al.</i> (2005); Gaughan <i>et al.</i> (2008); Kephart <i>et al.</i> (2010); Jacobs <i>et al.</i> (2017a)
Cold stress	Identified using clinical signs (shivering)	Hunter <i>et al.</i> (1999); Ontario Court of Justice (2014); Caffrey <i>et al.</i> (2017)
Frozen/frostbite	Identified by skin lesions and sometimes by the presence of ice	Schoning and Hamlet (1989a,b); Wellehan (2003); Goumon <i>et al.</i> (2013)
Dehydration	Identified by drinking behaviour and clinical signs	Jarvis <i>et al.</i> (1996)
Surface wounds	In pigs, skin lesions due to fighting can be identified and scored. Damage from driving instruments may also be apparent, e.g. reddened areas on the skin or petechiae in the anus of pigs and cattle	White (1999); Aaslyng <i>et al.</i> (2013); Blagojevic <i>et al.</i> (2015); Carroll <i>et al.</i> (2016, 2018)
Fractures and dislocations	Severe lameness often with limb dragged in a flexed position and non-weight bearing	Tiong and Bin (1989); Rakestraw (1996); Dalla Costa <i>et al.</i> (2019)
Bruises	Traumatic injury to the muscle that must be trimmed out. Caused by rough handling, bumping into sharp edges on handling facilities or overloading of trucks	Tarrant <i>et al.</i> (1992); Costa <i>et al.</i> (2006); Strappini <i>et al.</i> , (2009, 2012, 2013); Grandin (2015, 2017); Bethancourt-Garcia <i>et al.</i> (2019). For additional references, see Chapter 15
Poor body condition (skinny or emaciated)	Prominent bone structure with little evidence of fat deposits or muscling. Some thin animals may be weak and not fit for transport	Edmonson <i>et al.</i> (1989); Grandin (2015); Munoz <i>et al.</i> (2018)

stunner. An animal either falls down during handling or does not fall down. It is either poked with an electric goad (prod) or not poked with it.

Yes/no scoring works poorly for some welfare problems such as foot pad lesions in poultry or lameness. When yes/no or presence/absence scoring is used, each bird or animal is scored as either normal or has a foot pad lesion. It provides no indication of the severity of a problem. For example, a chicken with a small foot pad lesion that may be a minor welfare issue is combined in the same category with a bird that has a severe lesion that would cause pain. There is evidence that yes/no scoring may have better inter-observer reliability and training of

auditors is easier. To use this approach, a normal foot and a very slight foot pad lesion may have to be placed in an acceptable category and a more severe one is placed in the fail category. When the yes/no approach is used, each animal receives either an acceptable or not acceptable designation.

The next question is: how many categories should a scoring system have when a degree of severity is included? If there are too many categories, training of auditors becomes more difficult. The first author's experience and studies have shown that three should be the minimum number of categories and five should be the maximum. A three-point system would have

Table 16.2. Conditions associated with on-farm management that can cause pain or discomfort.

Welfare problem	Comments	References
Lameness	Identified using locomotion scoring and swollen joints	Mouttotou <i>et al.</i> (1997); Winter (2008); Jensen <i>et al.</i> (2012); Shearer <i>et al.</i> (2013); Angell <i>et al.</i> , (2015); Llonch <i>et al.</i> (2015); Edwards-Callaway <i>et al.</i> (2017); Deeming <i>et al.</i> (2018); Munoz <i>et al.</i> (2018)
Hernia	Scored by size, severity of skin lesions and proximity to the ground	Straw <i>et al.</i> (2009); Welfare Quality (2009b); Schild <i>et al.</i> (2015)
Rectal prolapse	Straining, protrusion and swelling of the rectum	Blagojevic <i>et al.</i> (2015)
Vaginal prolapse	Straining, protrusion and swelling of the vagina	Hardstaff <i>et al.</i> (2012)
Surface wounds in pigs	Areas with loss of body coat, skin redness and swellings can occur following trauma, infection and external parasites. In pigs, bite wounds can occur on the flank, neck, head, ears, vulva and tail	White (1999); Faucitano <i>et al.</i> (2001); Hardstaff <i>et al.</i> (2012)
Damaged or diseased eye	Trauma, cancer or infection of the eye can occur. High ammonia levels on the farm can cause eye damage	Hamir and Parry (1980); Miles <i>et al.</i> (2006)
Swollen leg joints (hock lesions)	Cattle housed indoors on a hard surface	Fulwider <i>et al.</i> (2007); Barrientos <i>et al.</i> (2013); Kester <i>et al.</i> (2014); Phythian <i>et al.</i> (2019)
Breast blisters (poultry)	Poor litter	Haslam <i>et al.</i> (2007); Allain <i>et al.</i> (2009)
Hock burn (poultry)	Poor litter	Allain <i>et al.</i> (2009)
Foot pad lesions (poultry)	Poor litter	Ekstrand <i>et al.</i> (1997); Michel <i>et al.</i> (2012); Heitmann <i>et al.</i> (2018)
Respiratory signs	Cough, nasal discharge, dyspnoea	Leruste <i>et al.</i> (2012); Llonch <i>et al.</i> (2015)
Diarrhoea	Faecal staining of the perineum	Hardstaff <i>et al.</i> (2012)
Nervous signs	Ataxia, circling, convulsions, paralysis etc.	Konold <i>et al.</i> (2006)
Dirty livestock or poultry ^a		Welfare Quality (2009c); McKeith <i>et al.</i> (2012); Grandin (2015, 2017); Saraiva <i>et al.</i> (2016); Lundmark <i>et al.</i> (2018); Munoz <i>et al.</i> (2018)

^aCleanliness is used in a number of animal welfare assessment schemes. Its relevance depends to some extent on the approach adopted for welfare assessment (Lassen *et al.*, 2006), but extremely dirty cattle may have discomfort because their hides are sometimes damaged.

Table 16.3. Examples of conditions associated with on-farm management that are assessed during inspection of the internal organs.

Welfare problem	Comments	References
Lung lesions (pneumonia)	The worst ones have adhesions to the chest wall	Hardstaff <i>et al.</i> (2012); Leruste <i>et al.</i> (2012); Rezac <i>et al.</i> (2014)
Liver abscesses	The worst ones have adhesions to the abdominal wall	Nagaraja and Lechtenberg (2007); Amachawadi and Nagaraja (2015)
Cardiac (heart) abnormalities	Brisket disease in cattle. Cardiac pathology associated with death losses	Neary <i>et al.</i> (2015); Newman <i>et al.</i> (2015); Zurbrigg <i>et al.</i> (2019)
Parasites	Liver flukes	Innocent <i>et al.</i> (2017)
Peritonitis	Can result in adhesions to the abdominal wall	
Stomach ulcers		Bršćić <i>et al.</i> (2011b); Swaby and Gregory (2012)

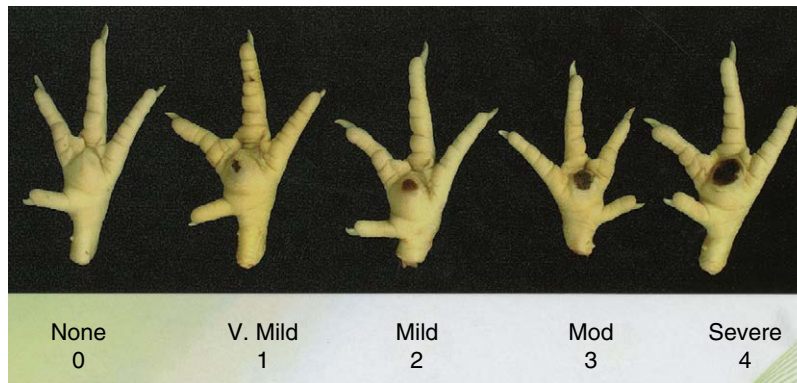


Fig. 16.1. Foot pad lesion scoring for broiler chickens, with four levels of severity. The bird that has a severe score 4 lesion would have much poorer welfare than a bird with a score 1 very mild lesion. If yes/no or absence/presence scoring is used, scores 0, 1 and 2 may be scored as acceptable and scores 3 and 4 as not acceptable. A score 4 must never be merged with a score 1 bird. (Photo from Temple Grandin, 2015.)

normal, mild and severe. A five-point system would have more gradations of severity.

Differences in numbering of scoring system

There are differences between published scoring systems on how the different categories are numbered. Grandin (2015) used 1 = normal, 2 = mild, and 3 = severe. It is becoming a more common practice to label the categories 0 = normal, 1 = mild, and 2 = severe (Welfare Quality, 2009a,b,c). When comparing data between different scientific studies or different abattoirs, make sure that everybody is using both the same scoring tool and the same numbering method. For commercial use and for scientific studies, both the scoring tool and its numbering system must be stated. For example, a four-point cattle lameness scoring was used with a 1, 2, 3, 4 numbering (Edwards-Callaway *et al.*, 2017). The welfare quality scoring tool for Welfare Quality (2009a) was used with a three-point numbering system. Another example is the three-point Bristol poultry gait scoring (Knowles *et al.*, 2008).

Do not use aggregate (integrated) scoring

When aggregate scoring is used, the scores for many welfare indicators such as lameness, injuries, foot pad lesions and other factors are combined into a single welfare score. This often works poorly because sometimes a severe problem where an audit should have been failed can be masked. One study of on-farm dairy audits had a farm with 47%

lame cows that was still able to pass a welfare audit (DeVries *et al.*, 2013, 2015). Good scores on other welfare measures masked the poor lameness scores. A dairy with almost half their cows being lame should fail a welfare audit. DeGraaf *et al.* (2017) found that the Welfare Quality integrated scoring system put too much emphasis on water troughs and not enough emphasis on lameness and mortality. Further concerns about problems with aggregate scoring are in Sandøe *et al.* (2017).

Comparisons between different farms

For many of the welfare indicators, there are big differences between the best farms and worst farms (Grandin, 2015). This is true for lameness in dairy cows (Cook *et al.*, 2016), death losses, downed non-ambulatory animals and swollen hocks in dairy cows (Fulwider *et al.*, 2007). Producers can be motivated to improve if reports are published so that they can determine how they rank compared with other producers (Chapinal *et al.*, 2014). Incentive pay can also be used to help reduce problems caused by either rough handling or poor management of housing.

Poultry Indicators of Poor On-farm Conditions

Compared with other species, poultry have welfare issues that are easy to measure. If a house has poor litter quality, there will be an increase in foot pad lesions, hock burn and breast blisters in broiler

chickens (Mayne, 2005; deJong *et al.*, 2014; Saraiva *et al.*, 2016). Some of the scoring tools that are available are breast blisters (Allain *et al.*, 2009), foot pad lesions (Ekstrand *et al.*, 1997; Dawkins *et al.*, 2004) and hock burn (Allain *et al.*, 2009; Saraiva *et al.*, 2016). There are many factors both on the farm and during handling and transport that will increase the percentage of dead-on-arrival poultry. Some of the factors are dirty birds, injuries and thermal stress (Jacobs *et al.*, 2017a). For abattoirs that process spent laying hens, there are easy-to-use scoring tools that are available online at Featherwel (2016) and Laywel (2006). These sites have pictorial scoring tools for feather condition and problems with feet and legs. These scoring tools can be used to determine if layers on the farm have either been pecked by other hens or have poor feather condition caused by a variety of housing problems on the farm (Morrissey *et al.*, 2016).

Wet litter will increase foot pad lesions in broilers (de Jong *et al.*, 2014). Allain *et al.* (2009) did extensive work on assessing hock burn and foot pad lesions. Foot pad lesions are a serious welfare issue, because they cause pain in turkeys (Wyneken *et al.*, 2015). The first author has observed that there are different types of lesions. Baby chicks will sometimes get damaged. When the bird gets older, this damage is no longer irritated and it has grown into whitish, rough tissue. The worst damage is caused by wet mucky litter. On a three-point scoring system, the worst footpads are ulcerated (Michel *et al.*, 2012). One study showed that new litter is not always better than old litter (Jacob *et al.*, 2016). This is why it is important to perform measurements. The first author has observed that maintaining sufficient ventilation rates is essential to keep litter dry. In cold climates, producers are reluctant to increase ventilation rates, because it increases costs to heat the barn. The percentage of soiled dirty birds should also be measured. The type of food fed to the birds may have an effect on bird cleanliness. Birds fed wheat and kept in a poorly ventilated barn during cold weather may have black tarry muck on them. Another factor that needs to be examined is genetic factors that may increase susceptibility to hock burn (Kjaer *et al.*, 2016). Slow-growing birds were less susceptible (Kjaer *et al.*, 2016). Dirty chickens can be easily assessed with a three-point system (Saraiva *et al.*, 2016): 0 = clean,

1 = soiling on breast, 2 = very dirty (dirt caked on feathers). Welfare Quality (2009a) also has a three-point system.

Cattle Indicators of Poor On-farm Conditions

When cattle are unloaded at the abattoir, it is easy to assess lameness, body condition, swollen leg joints and hock lesions. Cattle are one of the most extensively studied species. An increased prevalence of lameness, swollen leg joints or hock lesions is often associated with housing problems on the farm. There are some cattle that are definitely not fit for transport to an abattoir. These animals should have been euthanized on the farm. Animals that are not able to walk, are blind in both eyes, or females in the last 10% of gestation which are likely to give birth during transport should not be transported. Unfortunately, there are some dairy cows arriving at the abattoir in poor condition (Edwards-Callaway *et al.*, 2018). The Organisation for Animal Health (OIE, 2019), the EU and many producers have guidelines on fitness for transport. A recent study showed that there is often disagreement between producers and veterinarians on whether or not a cow was fit for transport (Dahl-Pederson *et al.*, 2018). Every producer, abattoir manager and truck driver should ask: how would this animal look if it was photographed on a phone and the video went viral on the internet? Phones are everywhere. If it would look bad on a phone and you would not want to show the pictures to your city friends, then do not ship it.

Lameness in cattle

Lameness is a serious welfare issue that causes pain (Flower *et al.*, 2008). The first author prefers the four-point lameness scoring system (Edwards-Callaway *et al.*, 2017). It is easy to use when trucks are being unloaded. It is the author's opinion that the three-point welfare quality lameness scoring loses too much information. In a three-point system, there is no differentiation between mild and severe lameness. The scores are 0 = normal, 1 = lame, 2 = downed non-ambulatory. A five-point system is too difficult for use under commercial conditions. For cattle, a three-point lameness score loses all measurements of severity. March *et al.* (2007) reported that it is easier to teach people to score

lame and normal cows. When a five-point lameness scoring tool was used, Schlageter-Tielo *et al.* (2014) found problems with inter-observer reliability. Agreement between observers was worse in differentiating mild lameness from moderate lameness. Below is a simple four-point lameness (difficulty in walking) scoring for cattle, pigs and other mammals when they are being unloaded from a truck (Grandin, 2015). It has been validated by Edwards-Callaway *et al.* (2017).

1. Walks normally with smooth, even steps.
2. Walks with a limp or has a stiff gait, with head down or bobbing head. The animal keeps up when a group of animals are walking (classify as mild lameness).
3. Walks with difficulty but still fully mobile. It cannot keep up and is left behind when a group of animals is walking (classify as severe lameness).
4. Can barely stand and walk, and may become non-ambulatory. Same as a score 5 on the Zinpro dairy cow scales (classify as severe lameness and not fit for transport).

It is easy for observers to differentiate between an animal that keeps up with the walking group or falls behind. This is the main factor that differentiates a score 2 from a score 3. Note that some guidelines will label normal walking as 0 and will number the degrees of lameness with 1,2,3. A detailed photographic guide to identify hoof lesions that cause lameness can be found on the Zinpro website (Zinpro, no date).

Lameness is often associated with housing problems, hoof diseases or swollen hocks (Fulwider *et al.*, 2007; Von Keyserlingk *et al.*, 2012; Higginson-Cutler *et al.*, 2013; Kester *et al.*, 2014). There is a big difference between the worst and the best dairy farms. In one study, the best dairy farm had 2.8% lame cows and the worst one had 36% (Cook *et al.*, 2016). One way to motivate producers to reduce lame cows is to publish reports on how a producer ranks compared with other producers (Chapinal *et al.*, 2014).

Dirty cattle

For scoring dirty cattle coming out of feedlots, McKeith *et al.* (2012) used a three-point system. A simple four-point scoring system used in Grandin (2015) is shown below. For most types of housing systems, this simple scoring system is effective. For cattle housed on dirt lots, the soiled area can range from slight discoloration of the hair to large

chunks of manure and dirt. Welfare concerns would be greater if large areas of the animal's body are covered with thick chunks of soil.

- 1 = Completely clean
- 2 = Legs are soiled, belly is clean
- 3 = Legs and belly soiled
- 4 = Legs, belly and sides of body soiled

If the '0 = normal' scoring system is used, the scores would be 0,1,2,3.

Cattle body condition score

The main causes of poor (skinny) body condition are either disease or poor nutrition. In extensively raised cattle, the body condition of cows may become thin during the dry season, but when the rains return the animals will fatten and regain condition. In an extensively raised animal there are many questions about what is an acceptable level of body condition. Figure 16.2 shows cows in the Australian outback during the dry season. The first author observed these cows and they were healthy and alert. For intensively raised dairy cows, many scoring tools are available (Wildman *et al.*, 1982; Ferguson *et al.*, 1994; Elanco, 2009). The author recommends using scoring tools that are recommended by the cattle producers in your country. Five-point scales are often used. There needs to be a pictorial score card to show a skinny body condition that is never acceptable. When body score data are being compared, it is essential to determine which scoring tools are being used. A search online revealed a wide variety of pictorial body condition scoring tools.

Udder problems

One of the most common problems is that the farmer fails to dry up a cow before shipping her to the abattoir. This will result in a distended udder that drips milk. This is a common welfare issue that must be corrected at the farm.

Neglected health problems in cattle

A large survey in the USA with both dairy and beef cattle indicated that timely marketing was a major problem (Roeber *et al.*, 2001). Producers should market cull cows to a slaughter plant before they deteriorate and become too debilitated for transport. Some common neglected health problems in cattle are necrotic cancer eye, where the eyeball has



Fig. 16.2. These thin cattle on the arid Australian outback are in good health and alert. When the rains come, they will fatten back up. Body condition scoring charts may have to be adapted to local conditions. If they become thinner than this photo, their welfare would probably be compromised. (Photo courtesy of Temple Grandin.)

ruptured, and necrotic infected prolapses. If the eye is not intact, the cow should not be transported (Canadian Food Inspection Agency, 2013).

Coat condition in cattle and bald spots

Bald spots on cattle are often caused by lice. When cattle normally shed their long winter hair, the new coat underneath is glossy. When they get lice, bald skin will be visible. Large bald spots on cattle are never acceptable. Bald spots are never caused by normal shedding of winter hair.

Abnormal behaviour in cattle

Tongue rolling is an abnormal behaviour that can be easily observed in a slaughter facility. The cow will raise its head and rapidly waggle its tongue. It is common in Jersey dairy cattle and it is associated with both genetic and environmental factors. It is an abnormal behaviour. Jerseys may be less likely to do it if they have access to pasture.

Internal organ inspection in cattle

Liver abscesses are discussed in Chapter 15. The worst livers have abscesses that adhere to the abdominal wall. The Elanco Scoring System (Elanco, 2019) does not differentiate between a severe abscess that adheres to the abdominal wall and one that does not. The Elanco system scores liver abscesses as normal, mild and severe with a three-point system. It is the first author's opinion that a fourth score should be added for adhering to the abdominal wall. Other internal problems that can be easily assessed are parasites, pneumonia and other disease conditions (Table 16.3). For a more detailed discussion, see the literature review in the second part of this chapter.

Injection site damage in cattle and pigs

Studies clearly show that injections of either vaccines or medicines deep into the muscle will damage the meat of cattle and pigs (Geaze *et al.*, 1996; Cresswell *et al.*, 2017; Ko *et al.*, 2018; Pfeiffer

et al., 2019). In beef, George *et al.* (1995) found that a deep muscle injection can cause an area of toughness 7–8 cm away from the lesion. This is the reason why cattle producers in many countries have stopped giving injections in the rump. They have switched to the neck position and use the subcutaneous route. In South America, injections in the rump are still common. Some medications and vaccines are more irritating than others. Injection site damage can range from old healed fibrous areas in the beef (Fig. 16.3) to more recent lesions with pus. A recent study showed that injection site damage is still a problem in cow carcasses (Pfeiffer *et al.*, 2019). There are good photos of fresh injection site damage in Ko *et al.* (2018).

Pig Indicators of Poor On-farm Conditions

The same four-point lameness systems (Grandin, 2015; Edwards-Callaway, 2017) can be easily used for lameness evaluation in pigs. During truck unloading, the pigs that lag behind when the group is moving are easy to see. Pigs have shorter legs and it may be more difficult to see the lame stiff-legged animals that can still keep up with the walking group. Pfeifer *et al.* (2019) found that inter-observer reliability for lameness was poor. For pigs, it may be best to use the Welfare Quality three-point scoring system (Welfare Quality, 2009b).

Breeding for good feet and legs can help prevent lameness (Le *et al.*, 2015).

It is possible that some problems with inter-observer reliability are due to the Welfare Quality pig-scoring system combining normal and mild lameness and then having two categories of severe lameness (Welfare Quality, 2009b). It may be easier for assessors to understand the following scale:

0 = Normal

1 = Fully mobile but lags behind a group of walking pigs during truck unloading

2 = Can barely walk and is almost a downer, non-ambulatory

From the first author's own experience, observing stiff lame cattle is much easier. In pigs, it is easy to differentiate between 0 = normal, 1 = lame and does not keep up with the group, and 2 = downer, non-ambulatory.

Dirty pigs

Pigs will roll in the mud to keep cool. This natural behaviour must not be confused with soil from dirty, poorly-maintained housing. For high-welfare sow herds, groups on straw bedding are often used. To keep the animals clean, sufficient bedding must be continually added to provide a dry, clean surface for the pigs to lie on. The biggest problem the first author has observed with these systems is failure to use sufficient bedding to keep the pigs clean.

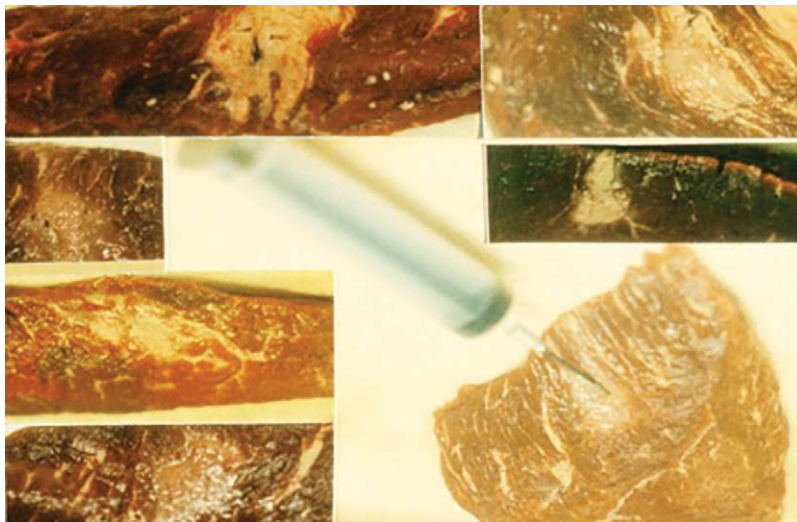


Fig. 16.3. Old healed injection site lesions in meat. Every injection with a needle damages the meat. More recent injection site damage may have pus or oozing fluid. (Photo courtesy of Temple Grandin.)

Body condition score in pigs

In intensively raised herds, pigs should be kept in good body condition. An easy way to determine if a sow is too skinny is to look for a series of vertebrae bumps down her back. A sow that is in good body condition will have a smooth back.

Skin lesions in pigs

Increasing the body condition of sows will help prevent skin lesions on the shoulder. Shoulder lesions often occur in sows housed in stalls. The presence of shoulder lesions cannot be used to identify producers who have sow gestation stalls where the sow is not able to turn around. The first author has observed shoulder lesions on sows housed in a straw-bedded pen. Lundeheim *et al.* (2014) found that thin back fat was associated with more lesions.

Hernias

Another problem that is relatively common in pigs is umbilical hernias. These can range from the size of a golf ball to a large distension dragging on the floor (Welfare Quality, 2009b). Pigs must be marketed before a hernia interferes with walking or gets injured by dragging on the floor. There is a genetic component to hernias (Grindflek *et al.*, 2018; Li *et al.*, 2019).

Tail biting and fighting in pigs and signs of abnormal behaviour

Pigs from certain farms or specific genetic lines may show more tail-bitten pigs compared with those from other farms. There are genetic differences in the tendency of pigs to tail bite, fight or chew on things (D'Eath *et al.*, 2009; Zunderland *et al.*, 2011; Chu *et al.*, 2017). Some pigs are naturally more aggressive (Chu *et al.*, 2017). Brunberg *et al.* (2013a,b) have done some interesting research on tail biting. Some pigs are the perpetrators of tail biting; others are more likely to tolerate having their tails bitten. Breeding programmes that select for rapid growth and lean backfat may have more problems. Within a group of pigs on a farm, there may be three types of pigs: (i) pigs that bite other pigs' tails; (ii) pigs that tolerate other pigs biting their tails; and (iii) neutral pigs who both avoid getting bitten or actively biting other pig's tails.

Scoring tools are available for assessing tail biting and scratches on pigs due to fighting. At an abattoir, it is possible to determine if scratches on pigs occurred during transport and lairage or if they occurred earlier in the pig's life. Carroll *et al.* (2018) found that many skin and tail lesions that occurred 10 weeks earlier could be observed at slaughter. A Swedish study indicated that providing straw helped to reduce tail biting. Tail docking is banned in Sweden, where at slaughter 1.6% of the pigs had bitten tails (Wallgren *et al.*, 2016).

Internal organ inspection in pigs

Two farm-related health problems that can be easily tabulated are lungs that adhere to the chest wall and gastric ulcers (Swaby and Gregory, 2012). Both of these are conditions that would definitely compromise welfare. Harley *et al.* (2012a,b) and Knage-Rasmussen *et al.* (2015) used meat inspection reports as an animal welfare surveillance tool. They examined the prevalence of tail biting and carcass condemnations at slaughter (see the literature review in the second half of this chapter for more information).

Problems with Livestock on High-dose Beta Agonists

Lameness, non-ambulatory animals and handling problems may be associated with high doses of the beta-agonists ractopamine and zilpateral. See Chapter 15 for a full discussion of this problem.

Sheep and Goats Indicators of Poor On-farm Conditions

Munoz *et al.* (2018) is an open access paper and has a table for scoring body condition, rumen fill, fleece cleanliness, fleece condition, skin lesions, tail length, dag (dirty breech) area, foot wall integrity, hoof wall integrity, hoof overgrowth and lameness.

Lameness

One advantage that assessors have when they score lameness in sheep, goats and cattle is that all three of these species will head bob while walking when they are lame. Munoz *et al.* (2018) used a four-point lameness scale for extensively raised ewes. They had good inter-observer agreement.

Foddai *et al.* (2012) contained information on scoring systems for foot rot in sheep.

Munoz *et al.* (2018) had a four-point scale:

- 0 = Normal
- 1 = Shorter stride, head bobbing
- 2 = Not weight-bearing on the affected limb
- 3 = Reluctant to move or stand

The Munoz *et al.* (2018) scoring tool is designed for on-farm use where evaluating animals walking as a group would not be possible. At an abattoir, livestock are unloaded from a truck and the four-point system (Edwards-Callaway *et al.*, 2017) would be easy to use for sheep or goats. Deeming *et al.* (2018) used both four-point and five-point systems for evaluating lameness in dairy goats. To use a five-point system accurately requires more training.

Dirty sheep and goats and hair coat condition

Munoz *et al.* (2018) found that the scoring system they used for fleece cleanliness and fleece condition had perfect agreement between four observers. Scores for dags (dirty breech area) had only moderate agreement. Hair coat condition is a valid indicator of dairy goat welfare (Battini *et al.*, 2015).

Munoz *et al.* (2018) used a four-point scale for fleece cleanliness and a three-point scale for fleece condition (see also Estevez *et al.*, 2017; Munoz *et al.*, 2019).

- 0 = Clean and dry
- 1 = Dry, slight mud/dirt
- 2 = Wet, some areas contaminated with dung
- 3 = Filthy, very wet and coated in mud or dung

Body condition score

Since sheep have wool, it is often difficult to assess body condition in live sheep with thick wool. Munoz *et al.* (2018) found that inter-observer agreement was poor. For accurate assessment of body condition in sheep at an abattoir, it is recommended that it should be done in the carcass after the pelt (skin) is removed.

Lesions and joint problems in sheep

Phythian *et al.* (2019) found that inter-observer agreement was high for assessing joint swelling.

Abnormal behaviour in sheep

Sheep living in confined systems will sometimes bite and pull the wool off each other. Feeding

programmes or close confinement can have an effect on wool pulling (Huang and Takeda, 2016, 2018). Wool pulling is abnormal behaviour that is detrimental to animal welfare. There are often individual differences in the tendency to wool bite.

Prohibited Surgical Procedures

It is easy to determine if an animal has had certain surgical procedures that may be prohibited, either in some countries or under a specific marketing programme.

- Tail docking of dairy cows. Research shows that docking provides no health or cleanliness advantage for dairy cows (Frantz *et al.*, 2019). Trimming the end of the switch is easy to do and should be used instead of tail docking.
- Mulesing in sheep (removal of strips of wool-bearing skin from around breech to prevent flystrike).
- Chopping long horns off large cattle.
- Tail docking in pigs.

Animal Welfare Issues that Must be Assessed with On-farm Visits

Provision of pain relief for surgeries done on the farm

Provision of analgesics and anaesthetics for surgeries such as castration or dehorning provides a reduction of stress and pain in cattle, sheep, pigs and goats (Stafford and Mellor, 2015).

Type of animal housing on the farm

Welfare criteria that specify a certain type of housing cannot be verified at the abattoir. Specific welfare requirements such as group sow housing or pasture access cannot be assessed at slaughter.

Euthanasia methods used on the farm

The public is increasingly concerned about the methods that are used to euthanize animals on the farm. There are many videos online that show euthanasia methods that are abusive and not acceptable. Evaluations at slaughter will not address this problem.

Environmental enrichment

There is increasing concern that livestock and poultry do not receive sufficient environmental enrichment

to fulfil behaviour needs. Some examples of methods to accommodate behaviour needs are nest boxes for hens, straw for pigs to root in or perches for poultry. The use of environmental enrichment on the farm cannot be assessed at the abattoir.

Abusive rough handling

Sometimes it is possible to observe injuries from abusive on-farm handling at the abattoir. This is especially true if the poor handling occurred recently (see Chapters 5 and 15). Other abuses such as rough abusive on-farm handling of young animals are impossible to evaluate on an older animal.

Detailed Review of the Literature on the Use of Abattoir Data for Animal Welfare Assessment

Ante-mortem and post-mortem inspection of livestock and poultry at a slaughterhouse provides a major collection point where animals from different farms could be assessed. There are many welfare issues that occur during rearing on the farm that can be identified at slaughter. Welfare issues associated with transport and slaughter can also be assessed at the abattoir (EFSA Panels, 2011) (Table 16.1). Assessments at slaughter will be especially useful in regions where on-farm welfare assessments are not performed. The existing regulatory frameworks and infrastructure for food safety inspection can be used to assess on-farm welfare (Stärk *et al.*, 2014).

Limitations of on-farm assessments

Many animals can be difficult to handle, examine and sample on-farm. It can be difficult to examine some animals fully and effectively on-farm and to score the severity of lesions, such as bite wounds in pigs. For example, on-farm pigs may be kept in highly stocked pens with poor lighting, and they could be resting and dirty, making inspection difficult (Dalmau *et al.*, 2014). If inspection or sampling at the slaughterhouse is effective, it can represent a more economical and safer procedure than undertaking on-farm examination or sampling (Schärrer *et al.*, 2015). If a blood sample or other tissue is required at the time of slaughter or post-mortem, there is no negative impact on animal welfare compared with sampling a live animal (Birkegård *et al.*, 2017). As there are strict biosecurity

measures, especially at pig and poultry farms, it is difficult to sample a large number of farms in a short period. Convenience sampling at an abattoir is inexpensive compared with undertaking numerous farm visits (Birkegård *et al.*, 2017).

There are some welfare conditions that can be more readily identified at the slaughter plant than during an on-farm inspection. Many types of injuries, such as bruising, skin wounds, footpad dermatitis and hock burns, are more apparent and more accurately recorded during post-mortem examination when the animals are on the slaughter line and after various degrees of processing, such as defeathering, scalding or skin removal, than during an on-farm inspection of live animals. Scalding in hot water cleans poultry carcasses and feet, making it easier to identify contact dermatitis after slaughter than in live birds. Scalding and hair removal from pig carcasses improves the visibility of tail lesions, severe skin lesions from fighting and lesions from trauma inflicted by handling instruments (Barrington and Jensen, 2013; Carroll *et al.*, 2016). Bruising cannot be observed in cattle and sheep until the skin has been removed.

Limitations of slaughter welfare assessment

The main problem with the use of slaughter data is that it is only suitable for the identification of health and welfare issues that cause lesions that are detectable at slaughter. The recording of lesions at the time of slaughter will not detect lesions that were present earlier in the life of the animal and have subsequently resolved (Sanchez-Vazquez *et al.*, 2011). It will not record pathology that was present in animals that died on-farm, were euthanized or were not fit for transport (Petersen *et al.*, 2008). The type and prevalence of health and welfare conditions identified at an abattoir are affected by whether the condition was readily recognizable on-farm, whether it was subsequently treated and whether preventive measures were instigated. Conditions that cause severe clinical signs were likely to be detected on-farm. Animals with mild or non-detectable clinical signs are more likely to be sent to slaughter than those with more severe external signs (Hardstaff *et al.*, 2012).

Several of the Welfare Quality schemes (finishing pigs, broilers and fattening cattle) for welfare assessment incorporate post-mortem abattoir recordings from batches of animals that were observed on-farm and scored using a range of

animal-based welfare indicators (Welfare Quality, 2009a,b,c). This requires good communication and planning with the slaughter plant to ensure that the animals assessed on-farm can also be assessed at slaughter. The slaughter plant assessments are confined to a limited number of specific lesions, mostly conducted on a sample of the animals from each batch. Most lesions are scored by reference to a description and image. ‘Warning’ and ‘alarm’ thresholds are set for the prevalence of each lesion. Some measurements use the meat inspection data collected by meat inspectors, whereas others require assessors to be present to collect additional data. De Jong *et al.* (2016) discussed some practical issues with the use of the broiler welfare assessment protocol. An additional 1–2 h per flock at a slaughter plant is needed as well as a welfare assessment during a farm visit. In Dutch slaughterhouses, the speed of the slaughter line only allowed a scoring system that identified either ‘no’ or ‘mild’ hock burn and the prevalence of condemnations for different lesions was not recorded by meat inspectors; only the total percentage of rejected carcasses was recorded (De Jong *et al.*, 2016).

Different approaches to assessing animal welfare at the abattoir

When considering data collection on animal welfare at abattoirs, there are differences in approach as to which of the conditions recorded at slaughterhouses are identified as relevant to animal welfare. Sometimes only conditions that instigate enforcement action on regulations to protect the welfare of animals are considered to be a welfare issue. Another approach is to identify a condition as relevant to animal welfare if it occurred on-farm or during transport following a management problem or some other form of human culpability (Blagojevic *et al.*, 2015). Many conditions are listed under the heading of animal health rather than animal welfare because they either pose a public health risk or are associated with an economic loss if control and treatment measures are not undertaken to reduce their prevalence and severity.

The approach taken in this chapter is that all conditions that are likely to have been associated with an aversive emotional state in the animal, such as pain or discomfort, are considered relevant to animal welfare. As a consequence, many of the conditions that are normally listed as animal health

conditions are considered to be relevant to animal welfare. This approach was also taken by EFSA Panels (2011) and Nielsen *et al.* (2017) when they discussed the use of meat inspection data for animal welfare assessment. Injuries and diseases identified either ante-mortem or post-mortem were likely to have been associated with experiences of pain, suffering and discomfort when the animals were on-farm and during transport to slaughter. Many diseases that cause gross pathology in animals are also likely to have caused the animals to feel ill and experience clinical signs associated with unpleasant sensations, such as inappetence, thirst, fever and nausea. Many of the diseases that cause identifiable lesions at the abattoir would have had poor welfare consequences for the animals when they were alive by causing them weakness, reduced ability to undertake important physiological functions, and to obtain feed, water and rest (Cockram and Hughes, 2018).

Determining the prevalence of animal welfare issues in a country, province or state

Within a country, there is a limited number of abattoirs through which almost all livestock and meat birds pass. This structure should provide an ideal opportunity for surveillance of animal welfare issues. Systematically collected data are essential for the accurate description of animal welfare issues that can then be used to contribute to the planning, implementation and evaluation of risk-mitigation actions by government or industry. Estimates of the prevalence of conditions relevant to animal welfare can be monitored over time and significant changes can be detected (Correia-Gomes *et al.*, 2016). To produce valid estimates, surveillance to measure the level of a welfare problem at an abattoir has to avoid bias and therefore needs to be based on either a census or a representative sample of the relevant population (EFSA Panels, 2011). Abattoir characteristics, such as the number of days or weeks on which animals are slaughtered, and the number of animals processed, may affect condemnation rates at different plants (Alton *et al.*, 2010). As animal welfare is a sensitive topic, many producers consider that information for their farm is confidential and access to their data should not be provided to external parties (Shadbolt *et al.*, 1987). However, there are ways of maintaining the anonymity of individual producers when regional or national statistics are compiled.

Use of abattoir data for enforcement of legal regulations on animal welfare

In some countries, if the prevalence of a specific welfare issue in a batch of animals exceeds an established 'target' value, or if the severity of a welfare issue in an individual animal requires action, a regulatory response may be instigated. In some countries, enforcement inspectors are required to identify welfare issues in live or dead animals that appear to have originated on-farm or during transport, gather evidence and report the details to the regulatory authority (EFSA Panels, 2011). In the EU, a directive (European Council, 2007) that regulates the on-farm stocking density of broilers requires slaughter plant monitoring of the prevalence of specific welfare outcomes to ensure that they do not exceed specified thresholds; or, if they do, the producer has to reduce the on-farm stocking density to a prescribed level. If a producer rears broilers at a floor stocking density greater than 33 kg/m² they must provide documentation on the daily mortality rate and the cumulative daily mortality rate and this is assessed alongside the percentage of broilers that are dead on arrival. The prevalence of post-mortem lesions (e.g. ascites/oedema, cellulitis and dermatitis, emaciation, joint lesions, septicaemia/respiratory lesions and foot pad dermatitis) that are indicators of contact dermatitis, parasitism and systemic illness cannot exceed specified thresholds (Butterworth *et al.*, 2016). Where levels exceed a threshold (trigger level), the owner/keeper of the birds and the government welfare regulatory authority are notified.

Use of Data Collected Primarily for Food Safety Reasons for Animal Welfare Assessment

Almost all food-producing animals (except those that die, or are killed, on-farm) are slaughtered for human consumption and subjected to ante- and post-mortem inspection at abattoirs. Although this information is collected primarily for food safety reasons, it is a valuable source of surveillance data for animal health and welfare at farm, regional and national levels. If this information is provided to the producer, it can be used to inform their herd/flock health planning. The relative merits of the use of meat inspection data to provide information on animal welfare have been discussed by several authors (Cleveland-Nielsen *et al.*, 2004; Harley *et al.*,

2012a; Stärk *et al.*, 2014; Huneau-Salaün *et al.*, 2015; Devitt *et al.*, 2016b; Correia-Gomes *et al.*, 2017; Grandin, 2017; van Staaveren *et al.*, 2017).

The aim of meat inspection is to protect public health by reducing the risk of hazardous material entering the food chain. An integrated 'farm-to-fork' approach is used to identify infectious risks to human health that may not be associated with gross pathology that is readily identifiable during post-mortem inspection. This can require the supplier of the animals to provide the abattoir with food-chain documentation on the management of their animals while they were on the farm (Butler *et al.*, 2003). Ante-mortem inspection, i.e. of live animals, is conducted to identify any clinical signs of disease in the animals that might affect human health and to identify diseases of economic significance to animal health. Ante-mortem inspection is increasingly used to identify any signs that animal welfare has been compromised during the handling and transport of the animals to the abattoir or during rearing on the farm of origin. The post-mortem visual inspection of the carcass and the viscera is designed to detect and withdraw from the food chain (i.e. condemn as unfit for human consumption) any carcasses and viscera that show grossly identifiable abnormalities that may affect their safety or wholesomeness. Condemnation statistics for carcasses, parts of carcasses and viscera will list the prevalence of conditions assessed as unfit for human consumption (Government of Canada, Agriculture and Agri-Food Canada, 2018a,b).

Food chain records as a source of information

Food chain information is information shared between farms and slaughterhouses, primarily to reduce the risk of food safety issues, but it also has relevance for meat quality, animal health and animal welfare. A producer (especially of pigs and poultry) is increasingly required to provide information on production performance and mortality during rearing to enable a veterinary inspector at the slaughter plant to evaluate the food safety risk associated with a batch of animals. However, there is a tendency for some producers to provide insufficient and inaccurate food chain information (Felin *et al.*, 2016; Allain *et al.*, 2018). Mortality rates during rearing provide useful information, but ideally, for welfare assessment, the records need to differentiate between animals that die and those

that are killed due to euthanasia. For all-in/all-out systems, the batch is identifiable and a batch mortality rate can be calculated. For continuous systems, where only some animals are selected for slaughter, the group is not as clearly defined and the mortality rate over a specific period is provided (Food Control Consultants, 2015).

Ante-mortem meat inspection of live animals as a source of information

The ante-mortem inspection of live animals in the lairage is intended to detect animals with clinical signs of disease that might pose an increased food safety risk because they could have a condition that might not readily be identifiable during post-mortem examination or might require more detailed attention during post-mortem examination. It can also be used to identify diseases that pose major risks to animal health. Depending on the type of condition identified, the ante-mortem inspection might be used to adjust the timing of slaughter to earlier than scheduled (if, for example, a condition is associated with discomfort or suffering) or, if there is a risk of contamination, to later than scheduled. Watson *et al.* (2011) provided examples of common conditions recorded ante-mortem in calves, sheep and pigs in Great Britain.

The ante-mortem inspection is also used to identify any signs that indicate that animal welfare has been compromised during handling and transport or that the animals are affected by conditions associated with poor on-farm management (Tables 16.1 and 16.2). However, the ante-mortem inspection might only have fair to moderate sensitivity for the detection of health and welfare conditions that produce obvious clinical signs (EFSA Panels, 2011). The sensitivity of ante-mortem inspection is affected by factors such as: the duration of the examination of each animal; whether the animals are observed during movement or by pen-side inspection; the intensity of the lighting; any overcrowding in the lairage pens; the skill and experience of the examiner; and whether specific case definitions for animal welfare conditions are provided (Petersen *et al.*, 2004; Schemann *et al.*, 2010; EFSA Panels, 2011).

If signs that animal welfare has been compromised are detected by abattoir staff during unloading or lairage and reported to an inspector, or are identified by an inspector conducting ante-mortem inspection, there can be an expectation or requirement

that an inspector will take specific actions directed at the transporter and/or the consignor of the animal(s) to reduce the risk of reoccurrence. Therefore, an inspector might be inclined only to record severe animal welfare conditions that require specific intervention. There is a risk that some less severe welfare conditions seen during ante-mortem inspection will not be recorded and this can reduce the value of ante-mortem inspection results as a means of identifying the prevalence of some animal welfare conditions (Food Control Consultants, 2015).

Limitation of data from meat inspection records

Meat inspection data is attractive as a data source as it saves time and resources on the collection of data and provides information from a wide geographical area (Houe *et al.*, 2011). However, there are several concerns about the accuracy and usefulness of meat inspection data for animal welfare assessment (Huneau-Salaün *et al.*, 2015; Mathur *et al.*, 2018). Information collected for primary databases that are used for research or advisory services is normally recorded using precise case definitions with instructions to assessors on how to identify and record the severity of each of the disease conditions. When secondary databases, such as meat inspection data, are used for a purpose that is different to that for which it was designed, there can be technical and practical limitations on their use (Houe *et al.*, 2011). There can be significant differences between the meat inspection condemnation rates for various conditions at different slaughterhouses due to inconsistencies between the visual criteria used by different inspectors to evaluate the reasons for condemnation (Lupo *et al.*, 2008; Schleicher *et al.*, 2013). Meat inspection results may be recorded with varying levels of detail. For example, lungs may be recorded as 'abnormal' or as showing signs of gross pathology associated with a specific case definition (e.g. enzootic pneumonia-like lesions) and sometimes with a measure of severity. Case definitions of post-mortem conditions that provide standard definitions for disease/condition categories in the form of text and photographs/diagrams can improve the consistency of recording (Food Control Consultants, 2015; Horst *et al.*, 2019). Compared with detailed systematic laboratory evaluation by trained pathologists, routine meat

inspection does not always provide the correct identification of some lesions (Bisaillon *et al.*, 1988; Nielsen *et al.*, 2015). There may be differences in the thresholds used to identify whether a lesion is recorded. Bonde *et al.* (2010) found that, compared with trained pathologists, meat inspectors tended to have a low sensitivity in that they may not have recorded less severe conditions, but they had very high specificity in that they required the presence of typical signs before they identified and recorded a condition.

The reliability of the recording of conditions can be affected by the number of conditions that meat inspectors have to record, their training and opportunities for continuing professional development (CPD) and the extent of the monitoring of inspection results between inspection teams, abattoirs or regions. The lighting, the speed of the slaughter line and the number of inspectors can also affect the reliability of data recording (Watson *et al.*, 2011; Food Control Consultants, 2015; Horst *et al.* 2019). Touch-screen terminals close to the inspection points that automatically identify the animal being inspected, or the batch to which it belongs, can be used to record meat inspection data. However, manual collection methods that utilize paper, boards, or mechanical counters are also used. These manual systems often require transcription, manual data processing or digital entry on to computer software when the inspector has completed their inspection period on the slaughter line (Food Control Consultants, 2015).

Problems with comparing meat inspection data between countries

When comparing the prevalence of conditions recorded using meat inspection data over time or between countries, there can be differences in the way in which conditions have been identified and recorded (Watson *et al.*, 2011). There is also a risk of double recording of the same post-mortem finding, e.g. pleurisy, in a single animal at both the carcass and offal inspection points, or an abscess could be recorded in more than one location (Watson *et al.*, 2011; Food Control Consultants, 2015). If multiple conditions are observed, only the dominant condition may be recorded. When a whole carcass is rejected, the viscera and offal may also be rejected without inspection. Superficial bruising may be trimmed and not recorded in condemnation data (Watson *et al.*, 2011).

Conditions Associated with Injury that Compromise Animal Welfare

Skin conditions in poultry

Although not part of normal meat inspection conducted for food safety reasons in poultry, foot pad dermatitis, hock burn and breast blisters are increasingly monitored on the slaughter line as part of quality assurance and animal welfare surveillance. These conditions are a form of contact dermatitis that occurs on-farm when the litter quality is poor. The prevalence and severity of footpad dermatitis, hock burn and breast blisters are affected by the litter quality, stocking density and other aspects of management during rearing. If the litter condition deteriorates, ammonia from the accumulation of urea in the litter causes a chemical burn on the skin and poor air quality (Haslam *et al.*, 2007). The severity of foot pad dermatitis can be scored on the slaughter line by the size and pathological characteristics of the lesions (Michel *et al.*, 2012; Heitmann *et al.*, 2018). Cellulitis occurs in poultry as a diffuse inflammation of the subcutaneous tissue. It can be associated with skin scratches from other birds at feeders that can introduce bacterial infection (Norton *et al.*, 1999; St-Hilaire and Sears, 2003). The prevalence of skin scratches in broilers is affected by the stocking density during rearing (Allain *et al.*, 2009). Spent laying hens can experience feather loss during the laying period. They can be scored for plumage condition (on the neck, breast, cloaca/vent, back, wings and tail), skin damage from feather pecking to the rear body and comb, and for aggressive pecking to the head (Tauson *et al.*, 2005).

Skin conditions in livestock

Photographic scales can be used to record the location and severity of skin lesions in pigs due to fighting (Faucitano, 2001). When the skin damage is caused by fighting during transport and lairage, more damage tends to occur on the head and shoulder areas than on the middle or rear of the pig. The lesions are typically comma shape, 5–10 cm long and numerous (Faucitano, 2001). Fresh wounds indicate that the damage likely occurred during transport and lairage. Healed (non-red) skin lesions, scars, notches and necrosis indicate older wounds that likely occurred on the farm (Dalmau *et al.*, 2014; Bottacini *et al.*, 2018; Carroll *et al.*, 2018). In pigs, tail bite lesions can be recorded as

injuries to the tail and by a short or missing tail. Skin damage on the middle, back and hind regions of pigs can occur due to inappropriate use of driving instruments, mounting by other pigs, or contact with overhead rails during handling (Geverink *et al.* 1996; Faucitano, 2001). The skin over joints such as the shoulder and over hernias can be examined for abscesses, abrasions and ulcers (Knauer *et al.*, 2007). Most ulceration lesions are due to external trauma or fistulation to the skin surface from an underlying condition. If granulation tissue is not present, the ulceration is likely to be recent (Barington *et al.*, 2016b). Occasionally skin erythema due to urine scald can occur in pigs due to inadequate bedding in transit or on-farm (White, 1999). Parasitic skin infection, e.g. fly-strike in sheep and mange in pigs, may be observed (Davies *et al.*, 1996; White, 1999; Wall and Lovatt, 2015). In cattle, hide damage can occur from the use of sticks containing nails during handling (Grandin, 2017).

Bruising on poultry and livestock

Bruising can be observed after defeathering of poultry, after skin removal in ruminants and on the skin surface of live pigs, but it is clearer after carcass processing (Barington and Jensen, 2013). Bruising can be present in subcutaneous fat and muscle. There are several methods for scoring the severity of bruising, but most involve recording the number, size, shape, colour, depth and location of the bruising (Strappini *et al.*, 2012). Differences in the way in which bruising is identified and recorded can have large effects on the reported prevalence (Knowles and Broom, 1990). The manner in which broilers are handled during loading can affect the degree of bruising observed on the slaughter line (Cockram and Dulal, 2018). Handling, conditions during transport (e.g. high stocking density) and mounting interactions during lairage can affect the occurrence of bruising in livestock (Kenny and Tarrant, 1987; Eldridge and Winfield, 1988; Tarrant *et al.*, 1992; Jarvis *et al.*, 1995; Costa *et al.*, 2006; Romero *et al.*, 2013; Goldhawk *et al.*, 2015; Dalla Costa *et al.*, 2019). The severity of haemorrhage and the amount of necrotic muscle tissue in a bruise are dependent on the force of impact (Barington and Jensen, 2016a). The pattern and shape of bruising can often resemble the object used to inflict the trauma (Barington and Jensen, 2016b). Excessive use of driving instruments

during handling can cause bruising (Geverink *et al.*, 1996). For example, in pigs and cattle, bruising in a tramline pattern consisting of two longitudinal, parallel lines of haemorrhage separated by apparently normal skin is indicative of trauma from the excessive use of a stick or bar. Bruising in pigs in the shape of the handle of a plastic pig paddle and the pattern of a metal chain has been recorded (McNally and Warriss, 1996; Barington *et al.*, 2016a). Skin-penetrating lesions due to excessive use of tattoo hammers can also occur in pigs (Nielsen *et al.*, 2014).

In cattle and pigs, a large proportion of the bruising seen on the slaughter line has been estimated to occur at the abattoir (McCausland and Millar, 1982; Strappini *et al.*, 2013; Barington *et al.*, 2018). The colour of a bruise is initially red, and then it changes through various shades of purple, green and yellow due to the breakdown of haemoglobin into bilirubin and biliverdin. It is difficult to accurately estimate the age of a bruise just from its colour (Barington and Jensen, 2015), but laboratory analysis can provide a reasonable estimate of the age of the bruising (Barington *et al.*, 2018). Some bruising seen on the slaughter line can be caused during stunning and post-mortem by machinery or the handling of the carcass (Hamdy *et al.*, 1961; Kranen *et al.*, 2000; Strappini *et al.*, 2009; Kittelsen *et al.*, 2015b).

Fractures

Fractures can occur in the wings and legs of broilers and laying hens during handling before loading, but also during shackling and electrical stunning at the abattoir (Gregory and Wilkins, 1990; Gregory *et al.*, 1990; Raj *et al.*, 1990; Newberry *et al.*, 1999; Kittelsen *et al.*, 2015b; Jacobs *et al.*, 2017b). Fractures can also occur at other sites, especially in birds that are dead on arrival (Kittelsen *et al.*, 2015a). In laying hens, wing and keel bone fractures can occur on-farm associated with cage and non-cage housing systems, respectively (Gregory *et al.*, 1990; Wilkins *et al.*, 2011). Leg fractures can occur in pigs during handling and transport (Tiong and Bin, 1989; Dalla Costa *et al.*, 2019). A recent fracture is likely to be recognized post-mortem by fresh haemorrhage at the fracture site (Hardstaff *et al.*, 2012). In cattle, a healed, broken tail due to poor handling can be apparent as a permanent bend or kink in the tail (Grandin, 2017).

Conditions Associated with On-farm Management

Emaciation and poor body condition

Emaciation can occur for several reasons, including overproduction, disease (e.g. parasites and wasting diseases), dental problems and undernutrition. Body condition score can be evaluated while the carcass is on the slaughter line (Knauer *et al.*, 2007). During processing, emaciated carcasses can be recognized as those with little subcutaneous and intracavity fat. Any carcass fat that is present tends to be oedematous and jelly-like in appearance (Hardstaff *et al.*, 2012). In poultry, a carcass condemned due to emaciation/cachexia has little muscle, almost no fat and a prominent keel bone. Emaciation in poultry is caused by poor management and chronic health conditions (Nery *et al.*, 2017).

Dehydration

Dehydration can occur due to water restriction during transport and lairage (Jones *et al.*, 1990; Brown *et al.*, 1999; Jacob *et al.*, 2006) and occasionally due to an inability to obtain sufficient water on-farm due to management problems, disease or heat. Dehydration can cause a loss in carcass weight, a drier appearance to the meat, a reduction in the contents of the gastrointestinal tract and greater difficulty in separating the skin (hide) from the subcutaneous tissues (Jones *et al.*, 1990).

Conditions associated with lameness

Arthritis (inflammation of a joint) is a common cause of lameness in pigs, cattle and poultry that is recognized post-mortem by swelling and excessive fluid in the joint (Cross and Edwards, 1981; Dupuy *et al.*, 2013). Arthritis can be caused by infection and degeneration of the joint due to a range of factors, including repeated trauma and structural abnormalities associated with genetics and rapid growth (Bradshaw *et al.*, 2002). In pigs, the prevalence of arthritis is affected by housing and on-farm management (Heinonen *et al.*, 2007). Scoring of lameness of poultry at an abattoir is extremely difficult. However, it is easier to measure abnormalities such as twisted legs. Knowles *et al.* (2008) has a good review of leg disorders in broiler chickens.

Tenosynovitis with or without tendon rupture can occur in broilers as a result of infection and trauma and cause lameness (Johnson, 1972; Duff

and Randall, 1986). Bursitis lesions are inflamed and enlarged bursae (fluid-filled sacs located where muscles and tendons move over bones). In pigs and cattle, they are caused by trauma and, in particular, pressure on hard surfaces during lying (Gillman *et al.*, 2008; Brščić *et al.*, 2011a). Bursitis can affect locomotion in finishing pigs (Kilbride *et al.*, 2009).

In cattle and pigs, lesions in the feet are a major cause of lameness. Although not normally part of routine meat inspection (the feet from pigs and poultry might be kept for human consumption), valuable information could be gained by an examination of the feet. Feet from cattle, sheep and pigs could be examined for the presence of claw and hoof wall cracks, heal lesions, abscesses, interdigital inflammation and abnormal overgrowth conditions (upward or inward curvature of the toes or excessive hoof growth) (Murray *et al.*, 1994; Knauer *et al.*, 2007; Foddai *et al.*, 2012; Nalon *et al.*, 2013). The condition of the feet in cattle and pigs can be affected by many on-farm factors: environmental, genetic, nutritional or infectious (Moultotou *et al.*, 1999; Pluym *et al.*, 2013). For ruminants, the lower part of the limbs (at the carpal and hock joints) and feet are normally removed and discarded early in the carcass dressing procedures, before the carcass is skinned (but they are sometimes left attached to the hide). Although the feet from a batch of animals could be examined after the carcasses have been processed and moved along the slaughter line, to avoid the risk of contamination this is likely to require a separate area and different personnel to conduct the assessment (Llonch *et al.*, 2015). Spent laying hens can be assessed for the severity of foot damage (inflamed bumble foot lesions) (Tauson *et al.*, 2005). Poor management of freestalls (cubicles) in dairy farms or stalls that are too small can cause swollen hocks in dairy cows (Fulwider *et al.*, 2007). Dairy cows with swollen hocks are more likely to be lame. There is a big difference between the best and the worst dairy farms in the percentage of lame cows (Espejo *et al.*, 2006; Grandin, 2015).

Conditions Associated with On-farm Management or Infection That Can Cause Aversive Pathophysiological Effects

Cardiovascular conditions

Ascites in broilers is an accumulation of fluid in the lungs and abdomen that can result in respiratory distress. It is caused by an imbalance between

oxygen supply and the oxygen required for rapid growth. The heart has to work harder than normal to maintain effective blood flow throughout the body and this can result in chronic congestive heart failure, increased systemic pressure and excess fluid. It is a multifactorial problem influenced by environmental, nutritional and genetic factors (Wideman, 2001; Julian, 2005; Hassanzadeh *et al.*, 2014). Pericarditis and endocarditis can occur in cattle due to traumatic reticulopericarditis and bacterial infection, respectively. These conditions can cause pain and discomfort; and if severe heart disease develops, this can be associated with respiratory difficulties and ascites (Buczinski *et al.*, 2010). In pigs, pericarditis can be caused by several types of bacterial and mycoplasma infection. Adhesions between the heart and the pericardium might cause discomfort (Buttenschön *et al.*, 1997).

In cattle, problems with brisket disease (congestive heart disease) have become more common (Neary *et al.*, 2015). Heavy Angus steers are more susceptible (Neary *et al.*, 2015). In the USA, heavy fed cattle may lie down and refuse to move. Thomson *et al.* (2015) called this fatigued cattle syndrome. In both pigs and cattle, there are some animals that do not tolerate physical exertion and there are various causes of this problem. The fatigued cattle problem is caused by a variety of factors such as genetic selection for carcass traits. Excessive concentrates in the diet or indiscriminate use of growth-promoting agents may also be contributing factors (Grandin and Whiting, 2018).

Respiratory conditions

Pneumonia (inflammation of the lung) can be recognized by palpation and identification of dark purple areas of consolidation that can be scored by the percentage of the lung area affected (Ostanello *et al.*, 2007). Animals with pneumonia will likely have experienced fever, inappetence (Escobar *et al.*, 2007), increased respiratory frequency and decreased tidal volume. The severity of these physiological effects is related to the degree of pathological changes in the lungs, such as the constriction of airways, accumulation of mucus within the lumen of airways, oedema and thickening of the mucous membranes (Reinhold *et al.*, 2002). In animals with pneumonia, reduced physiological function can result in hypoxia from impaired oxygen supply (Linden *et al.*, 1995). If an animal is showing signs of laboured breathing over a prolonged period, this

will result in an excessive respiratory effort, discomfort, distress and fatigue (Beausoleil and Mellor, 2015). Pneumonias in calves and pigs are multifactorial diseases involving several potential pathogens. The prevalence of pneumonia is influenced by environmental factors (e.g. housing and ventilation), factors affecting susceptibility to the pathogens, and management factors, such as mixing, stocking density, vaccination and biosecurity procedures (Stärk, 2000; Lorenz *et al.*, 2011). Air sacculitis in broilers is caused by bacterial infections and its occurrence is affected by several management factors (Gross, 1961; d'Arc Moretti *et al.*, 2010).

Pleurisy is an inflammation of the pleura (serous membranes that line the inside of the chest and enclose the lungs) that can be associated with pain and discomfort while breathing or coughing, due to the sliding of the inflamed visceral and parietal pleura against each other and from the development of adhesions. Pleurisy can develop after bacterial and mycoplasma infection and following pneumonia (Meyns *et al.*, 2011). Several management factors, such as biosecurity procedures, stocking density and mixing, are associated with the prevalence of pleurisy (Jäger *et al.*, 2012).

Hepatic and renal conditions

In cattle, sheep and pigs, parasites in the liver can cause hepatitis and cirrhosis that, if severe, can lead to weight loss and anaemia (Sanchez-Vazquez and Lewis, 2013). Jaundice can occur from excessive destruction of red blood cells or an accumulation of bilirubin associated with liver disease or a bile duct blockage (Pearson, 1981). On-farm parasite control measures can be based on the prevalence of liver conditions recorded in condemnation data (Innocent *et al.*, 2017; Mendes *et al.*, 2017). Liver condemnation due to hepatic lipidosis (fatty liver) can occur in cull dairy cows (Rezac *et al.*, 2014). Kidney conditions such as nephritis can be observed and scored by the extent of the macroscopic changes that can occur following various types of infections (Martinez *et al.*, 2006) (see Chapter 15).

Infection

Septicaemia is caused by the spread of pathogenic bacteria, and toxæmia is caused by the spread of bacterial toxins in the blood. In animals condemned with these conditions, a wide range of pathological changes will have occurred while the

animal was alive, including effects on the blood supply to the muscles (cyanosis and hyperaemia) and widespread inflammation of the viscera (Fisher *et al.*, 1998). Animals with gross pathology identified post-mortem as septicaemia would have experienced systemic illness, muscle weakness (Ochala *et al.*, 2011) and difficulty maintaining normal physiological function (Wester *et al.*, 2011; Olsen *et al.*, 2016). An abscess is a collection of pus contained within a fibrous capsule and is formed by bacteria. Abscesses can occur throughout the body, including the liver and lungs, and cause weight loss (Brown and Lawrence, 2010). Some abscesses arise from bacterial contamination following an injection (George *et al.*, 1995). Liver abscesses can occur in cattle following rumen acidosis and ruminitis caused by a high-grain and low-roughage diet (Nagaraja and Chengappa, 1998; Nagaraja and Lechtenberg, 2007). In pigs, abscesses can be found throughout the body as a result of tail biting and other types of trauma (Huey, 1996; Heinonen *et al.*, 2010; Ellerbroek *et al.*, 2011). Peritonitis is an inflammation of the peritoneal cavity and its serosal surface (peritoneum). It can be caused by systemic infection, trauma, or gastrointestinal ulceration, blockage or ischaemia (restriction of blood supply). In animals that are condemned due to peritonitis, there was likely to have been an initial systemic response and abdominal pain, followed by adhesion formation (Fecteau, 2005). Animals condemned due to mastitis will likely have experienced pain and discomfort and possibly sickness (Leslie and Petersson-Wolfe, 2012).

Dark-coloured meat

Although sometimes recorded as part of meat quality control and, if the meat is very dark, as part of meat inspection, the significance of dark firm dry meat (DFD) as an indicator of animal welfare is problematic. EFSA Panels (2011) suggested that the presence of DFD meat indicates ‘that the transport or lairage conditions did not comply with legislation or with codes of practice’. Although many of the risk factors for DFD in cattle, pigs and poultry are associated with less than optimal welfare conditions, the relationships between factors such as stress, exercise, cold exposure and the occurrence of DFD in susceptible animals are not fully understood (Mach *et al.*, 2008; Dadgar *et al.*, 2012). Therefore, the occurrence of DFD should be used to indicate that management practices should be

revised, but not as a trigger for regulatory action on animal welfare (see Chapter 15 for additional information).

Conditions Recorded in Condemnation Data That Have No Direct Relevance to Animal Welfare

There are several reasons for the condemnation of a carcass or viscera that do not have direct relevance to animal welfare. These include contamination (e.g. by faeces or gut contents), post-slaughter damage from machinery, poor plucking, over-scalding, pigmentation or abnormal colour, and abnormal smell. Condemnations due to poor bleeding can arise for several reasons not associated with inadequate exsanguination that might have delayed loss of consciousness or death. Therefore, quantifying the total number of condemnations might not provide sensitive or accurate information on animal welfare.

Feedback of Information to Producers to Improve On-farm Animal Welfare

As discussed above, there are on-farm risk factors for many of the conditions recorded during meat inspection (Bisaillon *et al.*, 2001; Lupo *et al.*, 2010). If abattoirs provide data on disease prevalence to producers and their veterinarians, this can be used to inform herd/flock health planning and enable them to make changes to their production systems to improve animal health and welfare, and potentially provide economic benefits (Dalmau *et al.*, 2014; Food Control Consultants, 2015). For example, the presence of some types of gross pathology such as lung lesions in cattle and pigs has been shown to reduce growth during rearing (Pagot *et al.*, 2007; Caucci *et al.*, 2018). There are also advantages to abattoirs if producers can reduce the prevalence of pathology in animals sent for slaughter. Abscesses and adhesions impede evisceration and this, together with the need for more detailed inspection and subsequent condemnation, can slow the slaughter line (Nagaraja and Chengappa, 1998).

Feedback to producers on condemnation data to identify subclinical disease present on a unit is potentially valuable. Some conditions that are not readily identifiable in live animals on the farm can be more readily detected during post-mortem inspection at the slaughterhouse (Green *et al.*,

1997; Food Control Consultants, 2015). Some examples are liver abscesses in cattle (Nagaraja and Chengappa, 1998) and poor rumen development and abomasal lesions in veal calves (Brščić *et al.*, 2011b). Some parasitic skin conditions can be more readily and objectively assessed during an inspection at slaughter than on-farm (Cargill *et al.*, 1997). Although bovine respiratory disease is commonly diagnosed on-farm using clinical signs of illness, monitoring of lung lesions at slaughter can be a more accurate way of identifying the prevalence of this condition (White and Renter, 2009).

For the provision of feedback to producers and their veterinarians, the number of conditions per animal or body part in the batch of animals should be calculated. When data is compiled and presented to producers and other stakeholders, the provision of categories by species, age and class of animal (for example, by differentiating between animals slaughtered in prime condition, young and cull animals) provides the most useful information (Food Control Consultants, 2015). Many producers do not effectively utilize the information provided by abattoirs (Shadbolt *et al.*, 1987; Meat and Livestock Commercial Services, 2013). Some producers express dissatisfaction with the accuracy and consistency of meat inspection results (Food Control Consultants, 2015; Devitt *et al.*, 2016a). Traditionally, when any information was supplied by an abattoir to a producer, it consisted of information on the weight, grades/classification, prices and deductions for condemnations (Pointon *et al.*, 2008). The producer would likely view the condemnation data with scepticism, as it would describe what financial deductions the abattoir had made for the product that was condemned or otherwise rejected, and would not necessarily consider the information to be accurate if there had been few signs of ill-health in the animals sent to slaughter. If an all-in–all-out system is used, all of the animals in a slaughtered batch will no longer be present on the farm and condemnation data might be considered to have less relevance than that for units where some animals reared in similar groups, or from the same group, are still present. However, for batch-reared groups, there can be common management issues that could affect subsequent groups of animals and condemnation data can be valuable (Heinonen *et al.*, 2001). There can also be a concern that data generated to assist producers might be used by regulatory authorities to enforce animal welfare standards (Devitt *et al.*, 2016a).

Benchmarking of information and providing data summaries to producers

Industry bodies have an opportunity to provide data summaries, analysis and benchmarking of meat inspection data to their members. In several countries, there are examples of national and industry systems that provide frequent feedback of benchmarked results from targeted abattoir inspections to participating producers and their herd veterinarians (Neumann *et al.*, 2014; Eze *et al.*, 2015). Holt *et al.* (2011) and Sanchez-Vazquez *et al.* (2011) described industry-financed initiatives that provided producers within the scheme with a report on every batch of pigs that they sent on specific days to an abattoir within the scheme. The report provided the farm-level frequency of gross pathological lesions observed in their pigs at slaughter. A more detailed inspection of a limited number of specific conditions than that undertaken for routine meat inspection was conducted by trained inspectors provided by the scheme. The inspection involved palpation and manipulation of the organs in addition to visual inspection (but no incision), and a measure of the severity of the lesion by reference to specific descriptions of the conditions to be recorded. Information on lesions was recorded directly on to hand-held touchscreen computers at the time of the assessment on the slaughter line. After each assessment day, the electronically recorded information was transferred electronically to a central database. The scheme provided training for assessors, quality control on the information recorded, data processing, analysis and electronic communication of reports, and knowledge transfer activities. This type of scheme has the potential to provide relevant information on the prevalence of certain diseases on particular farms and to identify management practices, e.g. vaccinations, parasite control and biosecurity practices, that minimize the risk of disease. The reports not only increase the awareness of producers and their veterinarians of individual problems present on their farms, but also provide a comparison between different units within their businesses and a comparison of their units with the industry as a whole. This benchmarking provides peer/industry pressure to control diseases and other welfare issues that cause identifiable lesions in their animals.

Traceability and the meat production chain

The ability to follow animals either individually or as a batch through the meat production chain is an

essential component of any system to utilize slaughter plant data to provide information on welfare issues during transport and on the farm. Food safety issues and commercial pressure on product quality have led to an increase in the use of systems for the traceability of live animals and the exchange of food chain information (Schwägele, 2005).

Traceability systems can be introduced by industry-wide private sector initiatives, individual supply chain initiatives and public sector regulation. A lack of adequate and standardized data collection and an effective means of data exchange can often mean that internal traceability (within a company) is easier than chain traceability (between companies in the supply chain) (Bosona and Gebresenbet, 2013). In the EU, abattoirs must have a traceability system that can identify the supplier of each animal that it receives (Schwägele, 2005). Cattle and sheep have to be individually identified and groups of pigs identified by their farm of origin. The electronic identification of animals makes it easier to follow animals through the supply chain. However, a frequent logistical issue is maintaining the identification of either individual animals or the batch during slaughter processes when the physical identification of an animal is removed when the head, hide, viscera and feet are separated from the carcass (Crandall *et al.*, 2013). Batches are usually identified on the slaughter line by local systems for marking the first and last animals in a batch.

Common interests between each of the partners in a supply chain can improve information exchange and result in benefits in product quality, food safety and animal health and welfare (Deimel and Theuvsen, 2011). Participation of producers and processors in cooperatives or specialized networks can be beneficial to the competitiveness of individual farms and companies. Producer cooperation with an abattoir can depend on many factors, such as the degree of mutual interdependence, the availability of other suppliers and processors, the price received by a producer from the abattoir, and whether there is personal contact between the producer and the abattoir (Schulze *et al.*, 2006).

Structure of the food chain and traceability

The degree of vertical integration in the supply chain can vary greatly between different sectors. In the pig and poultry sectors, there tends to be a high amount of vertical integration. Large vertically integrated pig and poultry companies often control

each stage in the production of pigs and poultry for slaughter. In most countries, nearly all of the pigs and poultry reared for slaughter are transported directly from a farm to the abattoir and are delivered in clearly defined batches (often separated into different rearing barns from the same unit). If cull poultry (breeding birds and laying hens) are sent to slaughter, they are similarly sent directly to a processor in defined batches. However, there is often a lack of vertical integration in some other sectors, such as the beef and sheep industries, where animals can pass through several different companies between birth and slaughter. Groups of cattle or sheep that arrive at a slaughterhouse may consist of: (i) animals that were born and reared on the farm where the animals were loaded; (ii) animals that were born on a number of different farms and finished on the farm where the animals were loaded; or (iii) mixed animals from a range of units that have come from a market or have spent only a short period on the farm where the animals were loaded. Cull dairy cows, cull breeding sows and boars may be sent to slaughter via dealers and collection centres and often arrive at abattoirs as mixed groups (Food Control Consultants, 2015). Mixed groups make it more difficult to provide traceability of animal welfare issues. If animals have moved and changed ownership in the immediate pre-slaughter period (e.g. finishers or dealers), the decision about which holding or farm of origin should be contacted in relation to welfare issues identified at slaughter is problematic. For animals that have undergone a finishing period, the most relevant party will depend on the duration of the finishing period and the nature and epidemiology of the problem(s) identified (Food Control Consultants, 2015).

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17 Approaches to Legislation and Enforcement to Minimize Welfare Issues Associated with Slaughter

MICHAEL COCKRAM*

Sir James Dunn Animal Welfare Centre, Atlantic Veterinary College, University of Prince Edward Island, Canada

Introduction

This chapter uses examples of legislation on slaughter mainly from North America and Europe to illustrate approaches to the drafting and enforcement of legislation, highlighting common themes, underlying principles and issues that have implications for animal welfare. In most countries, there is legislation designed to offer various levels of protection to farmed animals when they are slaughtered for human consumption in slaughterhouses (subsequently referred to simply as slaughter legislation). An appreciation of the risks of suffering during slaughter and the role of legislation in mitigating this risk is indicated by the priority that was given in many countries to the early introduction of slaughter legislation (Radford, 2001; Vapnek and Chapman, 2010) and by the presence of this legislation even when no equivalent national legislation has been introduced to protect farmed animals before they are sent to slaughter (Cowan, 2011). The development of global standards, such as recommendations on slaughter by Office International des Epizooties (OIE, now known as the World Organisation for Animal Health) (OIE, 2016), and the value of slaughter legislation in supporting international trade in meat products have provided governments with an incentive to introduce and update slaughter legislation. Most countries have some form of slaughter legislation that is to varying degrees consistent with OIE standards (Stafford and Mellor, 2009; Abyaneh *et al.*, 2019). However, in countries with a federal system, e.g. USA and

Canada, there can be national legislation that regulates federal activities, but not all States and Provinces necessarily have legislation that provides protection to animals that are slaughtered within their local jurisdiction (Whiting, 2013; Animal Welfare Institute, 2017; Fraser *et al.*, 2018). Some legislation is not comprehensive in the degree of protection that it provides. Some types of animals can be excluded and some slaughter procedures are exempt from some requirements.

Many different approaches are used in legislation to minimize the animal welfare issues that can occur during slaughter. In some parts of the world, e.g. the European Union (EU), there is detailed legislation that has widespread support, whereas in others, e.g. the USA, there is less support for legislation and more reliance on self-regulation and the use of voluntary schemes (Cowan, 2011).

Given that enforcement of food safety and animal welfare regulations occur at the same location, it is perhaps not surprising that there is considerable overlap between their approaches to legislation and enforcement. It is of interest to note the manner in which slaughter legislation has evolved to take account of developments in both regulatory policy and approaches to the regulation of food safety. The emphasis has moved away from prescriptive legislation that detailed how slaughter procedures should be conducted, with heavy reliance on direct inspection to identify non-compliance and the punishment of offenders. Regulatory policy is now often based on a cooperative model where

* Email: mcockram@upei.ca

the objective is to prevent identifiable animal welfare issues from occurring, and, when they do occur, to resolve these as rapidly as possible and attempt to update management procedures that will reduce the risk of their reoccurrence. Slaughterhouses are given responsibility for demonstrating their compliance with regulations and the enforcement agency is more focused on the oversight of these internal procedures rather than undertaking comprehensive and continuous direct inspection of each activity where animal welfare could be at risk. A broad range of enforcement tools is often available to facilitate a proportional approach to non-compliance that depends on factors such as the degree of suffering likely caused, the history of compliance and whether the slaughterhouse has a systematic procedure to reduce the risk of reoccurrence.

For legislation to be effective in achieving its objectives, it must be drafted well and adequately enforced. There is criticism of the manner of the enforcement of legislation both by industry, due to concern about its effects on economic performance, and by some pressure groups that are already concerned about the ethics of animal slaughter and then see graphic evidence of animal suffering during slaughter. Many companies and their industry associations have introduced policies, animal welfare standards and procedures to reduce the risk to their public and commercial reputation from non-compliance with animal welfare legislation.

Most legislation consists of primary legislation (e.g. Acts) that describe the underlying principles and secondary legislation (e.g. Regulations) that implement detailed provisions (e.g. methods of slaughter) and can be revised more easily and quickly than the primary legislation (Vapnek and Chapman, 2010). It is not the intention to describe the legislation present in each country in detail, as this can be readily obtained elsewhere and is subject to regular revision. It is important to note that where aspects of legislation and its enforcement are described, summary wording is often used rather than the original legal text. Therefore, to clarify legal aspects, it is important to refer to the original legal text.

Merits of Legislation

Due to different cultural attitudes to animals and the relative priority given to commercial activity, there are major differences in the perception of the need for legislation to protect the welfare of

animals at slaughter and the relative merits of voluntary or self-regulation versus legal regulation (Matheny and Leahy, 2007; Harlow and Rawlings, 2009). The principle that a society should legislate to prevent cruelty and impose a common animal welfare standard is dependent on a society's view on factors such as individual freedom, whether there is a culture of legal compliance and enforcement, and the balance of political forces that operate to decide public policy (Radford, 2001; Broom, 2009). In Europe, 'The protection of animals at the time of slaughter or killing is a matter of public concern that affects consumer attitudes towards agricultural products' (Council Regulation (EC) No. 1099/2009). In the USA, the Humane Methods of Slaughter Act (HMSA) was introduced because 'It is the policy of the United States that the slaughtering of livestock and the handling of livestock in connection with slaughter shall be carried out only by humane methods, as provided by Public Law ...'.

The major reasons for legal regulation are:

- to control risks to animal welfare;
- to level the commercial 'playing field' of compliance for companies involved in slaughter;
- to provide public accountability and assurance, without a conflict of interest; and
- to deter practices found to be morally unacceptable to society (Swanson, 2008).

In some countries, it is seen as the government's responsibility to set and enforce animal welfare standards that reflect societal expectations and industry realities. In this context, government intervention can be justified to:

- reduce the impact of market negative 'externalities', such as animal suffering, and/or to encourage positive 'externalities', such as policies to improve animal welfare;
- provide 'public goods', i.e. things that are shared by and benefit many in society, but which are not directly linked to any payment, e.g. high levels of animal welfare; and
- achieve social goals, for example in pursuit of a 'caring society' (Farm Animal Welfare Council, 2008).

Compliance with legal regulation is not without direct costs to the industry that is regulated and indirectly to the national economy, in terms of competitiveness, international trade and economic output, and there are costs to governments that have to provide funding for the resources to introduce,

inform and enforce the regulations (Bennett *et al.*, 2018). However, this has to be balanced against positive potential market benefits, for example from facilitating access to international markets by adopting internationally recognized high animal welfare standards for the production of meat and from avoiding the enormous adverse reputational costs to the whole sector (including the compliant majority) if publicity shows animal abuse by rogue operators (Bonafos *et al.*, 2010). Even companies that are regularly subject to enforcement activity for non-compliance use the fact that their procedures are subject to government oversight and regulation as a marketing tool in their publicity. There are also important indirect economic benefits from legally regulated standards to prevent animal suffering. For example, regulations on animal handling and effective stunning can result in safer and better working conditions for employees, improved meat quality and food safety and more efficient commercial practices (Hotis, 2006; Council Regulation (EC) No 1099/2009).

Industry has sometimes lobbied for minimal or no legal regulation with the following arguments.

- Voluntary regulation is more effective in achieving the desired outcome of minimizing risks to animal welfare.
- The market economy is the best way of determining what animal welfare standards the consumer desires.
- There is insufficient hard scientific evidence to justify many of the detailed animal welfare regulations that are sometimes proposed (Croney and Millman, 2007).
- Rigid prescriptive regulations restrict innovation and are slow to revise in line with commercial developments.
- The slaughter industry is already over-regulated and adopts high standards.
- Proposals for further regulation are mainly a mechanism for those opposed to animal slaughter to make the industry unsustainable.

It has also been suggested that it is not realistic for some slaughter procedures to always be performed with 100% efficiency, and that achievable performance targets that are included within voluntary standards have provided better improvements in animal welfare than legislation that in the USA requires, for example, mechanical stunning to be effective first time, otherwise the operator is not in compliance with the legislation (GAO, 2010).

Leaving consumers to decide which meat products to purchase on the basis of their ethical views is attractive for those who believe totally in an unregulated market economy (Sullivan, 2013). However, even if consumers were sufficiently informed about the relevant issues, most shoppers are influenced by factors such as price, appearance, advertising and habit, and their immediate priorities, rather than having to make a considered decision on all the relevant ethical issues connected with each purchase of a specific meat product. In addition, many consumers do not wish to think about the origin of meat products and do not like to dwell on the slaughter required to produce their meat. As discussed by Radford (2001), legal regulation can be seen as a reflection of a 'society's perceived collective values' and removes 'from the individual the responsibility of making a moral decision on every purchase'. Many of the benefits of improved animal welfare can be achieved by the adoption of voluntary standards as well as legal regulation (Broom, 2017). However, legal regulation provides an absolute minimal standard that applies to all slaughter plants specified in the legislation; it is relatively comprehensive in the coverage of risks to animal welfare; and the details and basis for the provisions in the regulations, and the criteria used for their enforcement, are transparent and publicly available (Lundmark *et al.*, 2018). Paolucci *et al.* (2015) audited a number of slaughter plants in Italy and found that, prior to the adoption of Council Regulation (EC) No 1099/2009, not all slaughter plants would have been in compliance with the legislation and they did not have the facilities, equipment and procedures necessary to reduce the risk of suffering.

Another option for the adoption of animal welfare standards is the use of Codes of Practice. These can provide practical advice on how to implement legal regulations, provide additional provisions to prevent welfare issues, and are often formulated using a consensus approach following input from industry and other stakeholders, leading to good industry 'buy-in'. They sometimes have legal status, for example by reference in legislation or by establishing industry norms of standard practice that are referenced during court proceedings. However, conflicts of interest can arise during the code development process if commercial interests inhibit the development of strict welfare standards or if there is a fear of subsequent assimilation of the code into law (Dale, 2009).

Types of Legislation

Cruelty provisions

The purpose of animal welfare legislation is to prevent suffering, not to punish people who are conducting socially accepted businesses (Whiting, 2013). For example, in the UK, an offence of cruelty cannot be committed if it is carried out during humane slaughter. However, in the absence of effective legislation and enforcement, cruel procedures can occur during slaughter. Examples of cruel procedures on conscious animals that are prohibited by legislation, but might otherwise occur, are:

- beating, throwing, kicking, dragging or dropping;
- poking out eyes, cutting tendons or the spinal cord to restrain or immobilize; and
- scalding, skinning, leg removal or other carcass dressing procedures (Stevenson *et al.*, 2014).

Although some slaughter legislation contains provisions that include the prosecution of cruelty as a criminal offence, this is often not an easy enforcement tool to use. It requires the prosecution to show that a person was motivated to commit a guilty act (*mens rea*) in that they intended the action and its consequences (Radford, 2001).

Developments in regulatory policy affect the design and objectives of slaughter legislation

Traditionally regulation was enacted by two separate parties: (i) the government as the regulator (mainly using prescriptive regulations, direct inspection and, if necessary, enforcement consisting of withdrawal of a licence to slaughter, a fine and occasionally criminal prosecution); and (ii) industry as the regulated entity (who, if found to be not in compliance with the legislation, would pay any penalty and/or follow the direct instructions of the inspectorate). This ‘command and control’ regulation was often written as standards that prescribed an approved procedure for a particular process (OECD, 2011; Gunningham and Sinclair, 2017).

In contrast, performance-based and management-based regulations are more flexible and less prescriptive. Performance-based regulations set objectives or standards for outcomes, such as what problems must be solved, or the goals to be achieved, and allow the regulated party some flexibility to determine how they will meet these objectives, rather than prescribing how to achieve these outcomes (OECD, 2011; Gunningham and Sinclair, 2017).

This allows them to identify processes that are cheaper and more efficient and allows innovation and faster adoption of new technology (OECD, 2002). Management-based regulation (or process-based regulation) requires businesses to demonstrate that they are meeting regulatory objectives through management processes that ensure a systematic approach to controlling and minimizing risks (OECD, 2002, 2011). The move away from command and control regulation has led to a focus more on management structures, incentives and self-regulation, with less reliance on conventional sanctions. In this ‘enforced self-regulation’ the regulator imposes a requirement for businesses to assess, control and monitor the risks to animal welfare at their establishment. The business determines and implements its own internal rules and procedures to fulfil the regulator’s policy objectives (Fairman and Yapp, 2005). With enforced self-regulation, the role of enforcement changes from identifying contraventions of rules designed to reduce risk, to assessing the systems that the business has in place for risk management. The move towards enforced self-regulation has occurred with the increased adoption of Hazard Analysis and Critical Control Point (HACCP) schemes. In these types of schemes, food businesses have to identify the hazards present within their operations, implement and monitor controls, and document this process. The business has to devise systems and rules to control the risks it creates. It has to implement these systems, monitor the results and record the outcomes (Gunningham and Sinclair, 2017). A risk is a combination of the likelihood of an adverse event (hazard, harm) occurring and of the potential magnitude of the damage caused (e.g. the number of animals affected and the severity of the harm) (OECD, 2014).

In Canada, this regulatory approach has been adopted in the Safe Food for Canadians Act 2012 and Safe Food for Canadians Regulations (SOR/2018-108) (Government of Canada, 2019a,b) (Box 17.1). This legislation contains some specific prescriptive regulations on how animals must be handled and slaughtered. In addition, it contains performance-based and management-based regulations that require the slaughter plant to:

- make an assessment of welfare risks;
- monitor procedures;
- undertake corrective action to address any deviations from humane handling and slaughter; and

Box 17.1. Terminology used in Canadian slaughter legislation and enforcement (CFIA, 2019b)

Animal welfare Preventive Control Plan

An animal welfare Preventive Control Plan (PCP) is a written systemic approach to humane handling and slaughter which is documented, auditable and detailing preventive measures relating to animal welfare.

Corrective action procedures

Corrective action procedures in the context of an animal welfare PCP are procedures that will address any deviations from the expected outcome of humane handling and slaughter of food animals. In general, these are designed to prevent recurrence of a deviation, although immediate corrective action procedures may be required to mitigate the suffering of an individual food animal.

Measures

Measures in the context of the animal welfare PCP are preventive measure procedures or protocols that

control the animal welfare risks in order to achieve an outcome of humane handling and slaughter of food animals.

Monitoring procedures

In the context of an animal welfare PCP, a monitoring procedure is an act of conducting a planned sequence of observations, tests or measurements to assess whether performance criteria are met or a preventive measure is effective.

Verification procedures

In the context of the animal welfare PCP, verification procedures are quality control evaluations of the monitoring procedures, to determine whether they have been effectively implemented as intended and provide the expected outcomes of humane handling and slaughter.

- develop written preventive measures that are effective at controlling the animal welfare risks in their establishment and provide evidence to demonstrate that they are effective at reducing and controlling animal welfare risks during all slaughter activities.

The required written preventive measures and evidence must include:

- a description of the performance criteria chosen to evaluate the expected outcome of each of the measures taken to control the risks;
- monitoring procedures for each slaughter activity associated with an animal welfare risk;
- corrective action procedures to be implemented for deviations from the expected outcomes of the measures in place;
- verification procedures used to check that the monitoring procedures are effectively implemented;
- procedures for conducting an animal welfare audit, on a regular basis, to evaluate the overall outcome of the measures; and
- documentation to prove implementation and show the supporting documents used to develop the plan.

The performance criteria can be written in a manner that recognizes that some procedures are

not always 100% efficient and that corrective action will only be required by the slaughter plant for equipment and processes if they fall below the agreed performance standard (critical control limits). However, corrective action is required if any animals experience suffering as a result of a less than perfect procedure (CFIA, 2019d). Provision of general information, advice and guidance from the regulator on the legislation and how it will be enforced (e.g. CFIA, 2019c) makes it easier for regulated entities to understand and meet their obligations (Harlow and Rawlings, 2009).

In the USA, the Humane Methods of Slaughter Act (HMSA) contains concisely worded performance-based regulations on handling and stunning in that they are required to be humane. However, the scope of the HMSA has attracted criticism (Mariucci, 2008). There is a prescriptive requirement for stunning by a single blow or gunshot, electrical or chemical methods, or other means that are rapid and effective, before restraint (shackling and hoisting) and exsanguination. The HMSA is a federal act that provides authority for the enforcement agency (United States Department of Agriculture, Food Safety and Inspection Service) (USDA FSIS) to introduce detailed regulations on facility design and operation, handling, stunning and enforcement (Code of Federal Regulations,

2017). There are no regulations that require slaughter plants to adopt written protocols. However, it is beneficial for an establishment to have a written document in place as it demonstrates to FSIS that procedures have been established to assure compliance with the HMSA, and it is taken into consideration if enforcement action is contemplated (FSIS, 2004, 2013). The following requirements are suggested for the development and maintenance of a systematic approach to humane handling and slaughter.

- Conduct an initial assessment of where and under what circumstances livestock may experience excitement, discomfort or accidental injury while being handled, and where and under what circumstances stunning problems may occur.
- Design facilities and implement practices that will minimize excitement, discomfort and accidental injury.
- Periodically evaluate handling methods to ensure that they minimize excitement, discomfort or accidental injury, and periodically evaluate stunning methods to ensure that all livestock are rendered insensible to pain by a single blow.
- Respond to the evaluations, as appropriate, by addressing problems immediately and by improving those practices and modifying facilities when necessary to minimize excitement, discomfort and accidental injury to livestock (FSIS, 2011).

Although poultry are not included in the HMSA, FSIS directives (FSIS, 2005) describe the use of a written systematic approach to humane handling similar to that described above for the HMSA, together with reference to industry guidelines on poultry welfare at slaughter (National Chicken Council, 2019). This is an example of co-regulation where the regulatory role is shared between government and industry by the enforcement agency endorsing an industry code of practice (OECD, 2002).

In the EU, Council Regulation (EC) No. 1099/2009 of 24 September 2009 on the protection of animals at the time of killing contains performance-based requirements to prevent avoidable pain, distress or suffering, including the provision of physical comfort, protection from injury and avoidance of prolonged withdrawal of feed and water. There are management-based regulations that require standard operating procedures (SOPs) to be developed and implemented for all the different operations, for example receiving animals, lairage,

restraint, stunning and exsanguination. The SOP has to detail the process so that it:

- explains the role of each individual in the activity it covers and all of their duties and responsibilities; and
- details who is responsible for: ensuring that the process is carried out correctly; carrying out assessments on critical stages, including monitoring for signs of unconsciousness; and taking any action necessary to ensure that the process is fully compliant with legislation.

Guides to good practice have been developed by industry (e.g. British Meat Processors Association, 2015; British Poultry Council, 2015) to assist with compliance with slaughter legislation.

Relationships Between Slaughter Legislation and Food Safety Legislation

There are many relationships between humane slaughter legislation and food safety legislation. In the EU, scientific advice on animal welfare issues is provided through the European Food Safety Authority (EFSA, 2019) as part of an integrated food chain approach to food safety (Horgan and Gavinelli, 2006). Many food safety regulations require a slaughter plant to adopt HACCP-based procedures (Hulebak and Schlosser, 2002). This change in the philosophy of food legislation, in which the emphasis moved from prescriptive legislation to legislation based on an assessment of risk, identification of Critical Control Points (CCPs) in the process where it is necessary to control these hazards, establishment of critical limits to monitor the effectiveness of control measures at CCPs and monitoring of CCPs (Green and Kane, 2014), has been mirrored in the way in which some humane slaughter regulations have been written.

Oversight of food safety at slaughterhouses is an important policy priority for governments (Henson and Caswell, 1999) and this has resulted in detailed legislation, establishment of an enforcement agency and the permanent presence of food safety inspectors at slaughterhouses. It was cost-efficient to add the regulation of humane slaughter to the food safety duties of the food safety agency. However, there are several consequences arising from adding the regulation of humane slaughter to existing food safety duties (Welty, 2007; Roy, 2015).

- Given the risk to human health, food safety is the overwhelming priority of the enforcement agency, rather than animal welfare (Leary *et al.*,

2016), as shown by examples of the names of various agencies, namely, the USDA Food Safety and Inspection Service (FSIS, 2019a), the UK's Food Standards Agency (FSA, 2019a) and the Canadian Food Inspection Agency (CFIA, 2019a).

- Most inspectors undertake their food safety work post-mortem by continual inspection of carcasses and processes, rather than ante-mortem or during slaughter, and therefore additional time and resources have to be provided to undertake inspections ante-mortem and during slaughter.
- Undertaking animal welfare duties requires specialist knowledge in addition to that required for food safety duties.
- Inspectors can be overburdened by having to undertake a range of duties.
- A greater range of enforcement tools, e.g. those related to meat inspection, can be available to enforce humane slaughter regulations.

As slaughter plants are a food business, non-compliance with legal regulations can be treated as a food safety violation. These administrative enforcement measures can include restrictions or prohibition of placing meat products on the market, suspension of meat inspection operations and closure of all or part of the business (Kettunen *et al.*, 2017), revoking or suspending a slaughter plant's licence and condemnation of carcasses as unfit for human consumption due to animal welfare issues. There are several examples from the USA on the use of food safety regulations to achieve animal welfare outcomes.

1. The federal meat inspection regulations require that all non-ambulatory cattle be condemned (FSIS, 2009). The incident that led to this regulation (abusive handling of non-ambulatory cattle) prompted FSIS to request that the company involved undertake a voluntary recall of all beef produced by that plant during the previous 2 years (USDA, 2009).
2. Poultry are not included in the HMSA. Some protection for poultry is provided by regulating food safety requirements (rather than by a specific animal protection regulation) contained in the Poultry Products Inspection Act in that it requires that poultry must die from slaughter. The associated regulations require that live poultry be handled in a manner that is consistent with good commercial practices (which is taken to mean that they should be treated humanely) and in a manner that results in thorough bleeding of the poultry carcass, and ensures that breathing has stopped before scalding, so that the birds do not drown (FSIS, 2005).

Carcasses of poultry showing evidence of having died from causes other than slaughter are condemned. Good commercial practice is assessed using the following criteria.

- Employees should be trained in handling birds with no fracturing of the legs of birds to hold them in shackles, or throwing live birds into a discard barrel.
- In cold weather, birds are not allowed to freeze inside cages or become frozen to cages.
- In warm weather, birds are not allowed to die from heat exhaustion.
- Employees should not drive over live birds with equipment or trucks.
- Employees should be trained in the proper use of stunning equipment and birds are not allowed to enter the scalding tank while still breathing (FSIS, 2015).

The effectiveness of the use of meat inspection legislation to regulate the humane slaughter of poultry in the USA has been heavily criticized (Animal Welfare Institute, 2016) and the exclusion of poultry from the HMSA is significant. The evidence that poultry can experience suffering is as strong as it is for mammals (Gentle, 2011) and they are just as (if not more) susceptible to welfare issues at slaughter as mammals. The total weight of poultry production in the USA is similar to that for red meat production; and in terms of numbers of animals, poultry slaughter is measured in billions of animals per year, whereas total red meat production is measured in millions of animals per year (USDA, 2016).

3. The Federal Meat Inspection Act provides authority for the appointment of inspectors at slaughter plants to prevent inhumane slaughtering of livestock by examining and inspecting the methods used for handling and slaughter.
4. If the handling and slaughter of livestock are not compliant with the HMSA, FSIS can refuse to provide or can temporarily suspend meat inspection at a slaughter plant, until the establishment furnishes satisfactory assurances on future handling and slaughter.
5. Inspectors can slow the slaughter line speed if there are deficiencies in carcass preparation or if carcass inspection requires more time.

Animal Welfare Expertise Present in Slaughterhouses Due to Legislation

Legislation can require the presence of specific types of trained people at slaughterhouses with a

duty to oversee compliance with regulations on humane slaughter, namely an animal welfare officer and a veterinarian.

Animal welfare officer

In the EU, Council Regulation (EC) No. 1099/2009 requires slaughterhouse operators (other than small slaughterhouses) to appoint an animal welfare officer. The animal welfare officer is employed by the slaughterhouse to act as the contact point for the enforcement agency, provide guidance to the other employees, ensure that SOPs are developed and put into practice, and require completion of any remedial actions necessary to ensure compliance with regulations (European Commission, 2012). The animal welfare officer must have sufficient authority and technical competence to undertake their duties, including possession of a certificate of competence for all the operations taking place in the slaughterhouse for which they are responsible. The animal welfare officer must keep records of their actions and report to the slaughterhouse operator on animal welfare issues, especially if these require a managerial decision.

Veterinary inspector

A veterinarian is required to be present at most slaughterhouses to evaluate the health of animals before they are slaughtered (ante-mortem inspection and assessment of the food chain information provided on each consignment of animals). Their other duties include monitoring the welfare of live animals and slaughter operations. Veterinarians make professional decisions guided by: their knowledge, understanding and experience of the issues; their adherence to ethical behaviour, professional standards and guidelines; and the legal framework (Devitt *et al.*, 2014). They give priority to animal welfare, while appreciating the need to balance animal welfare with other demands on the slaughterhouse operator (Whiting, 2013). However, in situations where there is only one veterinarian present in the same slaughterhouse for a prolonged period, there is a risk of not recognizing issues that require intervention and so job rotation has been suggested (Luukkanen and Lunden, 2016). Veterinarians are highly educated and have been considered to be the best-qualified generalists to oversee animal welfare matters (Farm Animal Welfare Council, 2003). Whether the existence of a veterinary qualification is

in itself sufficient to constitute the expertise required has been questioned (Radford, 2001). Veterinarians require specialist knowledge for the supervision of the welfare of animals at slaughter. Studies and audits have indicated that they would often benefit from an improved understanding of the principles of animal behaviour and welfare (Hötzel *et al.*, 2018). A report by the European Commission's Food and Veterinary Office (FVO) concluded that insufficient training of veterinarians on animal welfare at slaughter contributed to an inadequate assessment of the effectiveness of stunning, resulting in unnecessary suffering where electrical methods were used (FVO, 2008).

Enforcement

Legislation on its own is not sufficient; to be effective in achieving its policy goal it has to be enforced (Radford, 2001; OECD, 2014). Ineffective enforcement can occur from under-inspection or insufficient or poorly implemented enforcement action (OECD, 2014).

Developments in regulatory policy affect the objectives, approach and type of tools available for the enforcement of slaughter legislation

Compliance strategy

The overall aim of most regulatory policies is to achieve the highest possible levels of compliance with the law at the least cost to the regulated businesses. The predominant enforcement approach used for slaughter legislation is a compliance strategy that recognizes that most businesses want to comply with the law, and therefore a cooperative and proportional response to non-compliance is adopted. With this approach, enforcement has become a process of negotiation rather than confrontation. The compliance strategy has the main objective of securing compliance and remedying a problem, rather than punishing the offender (Gunningham and Sinclair, 2017).

The regulations are written to reflect that the primary responsibility for compliance and animal welfare lies with the regulated business. Regulations often require self-monitoring, and inspections by the enforcement authority focus on verifying how effective the self-monitoring and risk-management systems implemented by the business operator are.

However, it is still important for the regulatory agency to assess whether these systems work in practice and not only on paper.

If primary control measures, which are advice and negotiation, fail to induce appropriate correction of non-compliance, an enforcement agency can force an establishment to comply with regulations by using administrative enforcement measures, also called coercive measures or formal enforcement actions (Kettunen *et al.*, 2015).

Administrative procedures versus criminal prosecution

Administrative tools such as improvement notices are used rather than criminal justice proceedings. Criminal sanctions are costly and time-consuming for both businesses and regulators (Harlow and Rawlings, 2009). Administrative processes can be used to intervene at an early stage and obtain a rapid improvement in the situation (Radford, 2001). For example, in the EU, a certificate of competence is required to undertake specified procedures (Council Regulation (EC) No 1099/2009). This certificate can be suspended or revoked if the holder:

- is no longer assessed to be a fit and proper person;
- is no longer competent to carry out the operations which the certificate authorizes;
- has failed to comply with any provision of the regulations; or
- has been convicted of an offence under any animal welfare legislation (FSA, 2019b).

Prosecutions are rare and are normally only taken when there is repeated non-compliance with administrative procedures. With slaughter legislation, the regulatory officials are permanently located within the business's premises, and therefore the use of administrative procedures is more conducive to maintaining a continuing relationship with the business (Kettunen *et al.*, 2017).

Factors affecting the type of enforcement action

The type of enforcement action taken is dependent on a number of factors, including:

- whether any animal suffering occurred (e.g. injury or distress);
- the severity of suffering;
- the compliance history of the establishment;

- whether the specific non-compliance occurs repeatedly;
- whether the establishment has protocols and management procedures in place to reduce the risk of suffering;
- the response of the operator to an inspection and the identification of violations; and
- whether the incident was:
 - the result of an error of judgement;
 - the result of an unjustifiable or deliberate act; or
 - accidental.

Compliance history

If there has been a history of repeated and systematic violations, the enforcement response is greater (e.g. immediate escalation of sanctions) than for an establishment that previously had good compliance, where they are given an opportunity to correct the situation (OECD, 2014).

Opportunity to remedy non-compliance before taking enforcement action

Informing a business of an intention to take action and offering them an opportunity to discuss the specific compliance issue and put it right before action is taken is considered good regulatory practice. In the USA, FSIS often issues a notice of intended enforcement action (NOIE) to enable an establishment to respond to a non-compliance with corrective action before any enforcement action is taken (FSIS, 2017). The NOIE requests that the establishment responds with a document that:

- identifies the specific reason(s) why the events described occurred;
- describes the specific action(s) that will be implemented to eliminate the cause of the incident and prevent future recurrences;
- describes the specific future monitoring activity or activities that the establishment will employ to ensure that the actions implemented are effective; and
- provides supporting documentation and records associated with the proposed corrective actions and preventive measures.

Severity of animal welfare issue

In the UK, the Food Standard Agency (FSA) uses a numerical score from 1 to 4 (1 = Welfare compliant;

2 = No immediate risk to welfare; 3 = Potential risk to welfare; 4 = Welfare critical) to indicate the severity of an animal welfare issue (FSA, 2019b). Inspectors are required to take enforcement action every time animal welfare is compromised and an animal is suffering. If the welfare of an animal is compromised, the inspector must take direct action, for example to ensure that an animal is killed as soon as possible (FSA, 2019b). Some acts are considered unacceptable and they are described as egregious inhumane treatment (FSIS, 2011) or deliberate acts of cruelty (CFIA, 2019d). In these cases, immediate action is required by the operator and/or by the inspector to address the issue.

Escalating enforcement action

Most enforcement strategies involve step-wise interventions characterized by an ‘enforcement pyramid’. Informal advice and discussions may be followed by persuasion, formal warnings, administrative

action and, rarely, by criminal proceedings (Gunningham and Sinclair, 2017) (Fig. 17.1).

Use of food safety procedures to enforce animal welfare regulations

In the USA, the HMSA is enforced using a range of potential enforcement tools related to food safety regulation (Federal Meat Inspection Act) (FSIS, 2004). If non-compliance is observed, one or more of the following enforcement actions might be undertaken.

- Non-compliance report: a document is issued to the slaughter plant that describes the violation and the actions needed to correct the deficiency.
- Regulatory control action: a reject tag (as used in meat inspection for the retention or rejection of a meat product as not fit for human consumption) is placed on a piece of equipment or an area of the plant that was involved in harming or inhumanely treating an animal. The tag

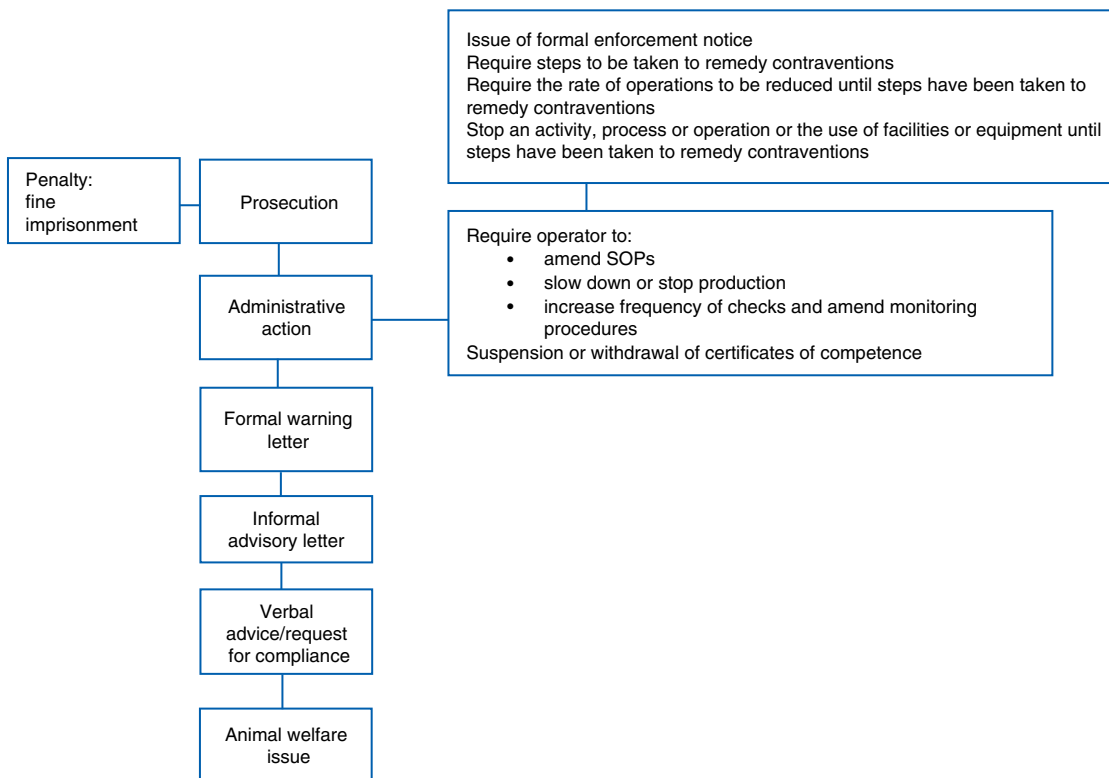


Fig. 17.1. A simplified example of escalating enforcement action (FSA, 2019b).

prohibits the use of a particular piece of equipment or area of the facility until the equipment is made acceptable.

- Suspension of plant operations: inspection services at the plant can be stopped immediately. The facts are documented and provided to plant management and senior management in the agency. They assess the facts supporting the suspension and take any final action. This acts as an economic deterrent, but it is common for a plant to be shut down for less than a day. As soon as the plant provides an acceptable plan for corrective actions and preventive measures, the suspension is removed. If this corrective action is approved, the enforcement action is deferred.
- Withdrawal of plant operations: if the plant fails to respond to concerns about repeated and/or serious violations, inspection services at the plant are withdrawn and products cannot enter interstate or foreign commerce. The plant must then reapply for and be awarded a grant of inspection before it may resume operations.

Publicizing enforcement action

Some enforcement agencies have adopted ‘naming and shaming’ strategies, including the publication of results of inspections, prosecutions and notices, or use of high-profile prosecutions. These deterrent measures are aimed at increasing the costs associated with reputational damage, increasing the perception of the probability of detection and as a means of satisfying public concerns over the level of enforcement of legal regulations (OECD, 2014; Gunningham and Sinclair, 2017). Enforcement actions from the past year that FSIS has taken against establishments that have been found in violation of the HMSA are published by FSIS (2019b).

Assessment of the effectiveness of enforcement

Assessing the effectiveness of inspection and enforcement by an agency is difficult. Improvements or deterioration in outcomes cannot be directly attributed to the activities of an enforcement agency, because of the large number of other factors that can influence these outcomes (OECD, 2014). The effectiveness of legislation cannot be reliably assessed by the number of enforcement actions taken. Enforcement action is a reflection of failure, as it is not required if there is compliance

with the regulations (Radford, 2001). Reporting a small number of records of enforcement activity does not necessarily mean that compliance is high: it may just be a reflection of a lack of inspection resources or lax enforcement. The numbers of reported cases of enforcement action are low in relation to the numbers of animals that are slaughtered (FSA, 2015c, 2019c; FSIS, 2019c). Performance measurement of effectiveness requires the use of a range of indicators from various sources and random statistically-representative surveys conducted periodically to determine industry compliance in critical areas (OECD, 2014). These can include the results of independent audits conducted for industry (Grandin, 2010) and those from enforcement agencies. In the EU, audits of compliance by member states with Council Regulation (EC) No 1099/2009 are published by the European Commission’s Food and Veterinary Office (FVO, 2015, 2019). In the UK, the Food Standards Agency (FSA, 2015b) publishes the results of compliance audits.

Difficulties with enforcement

There have been claims that there has been significant under-enforcement of legislation on humane slaughter, especially in the USA (Jones 2008; Mariucci, 2008; Friedrich, 2015; Animal Welfare Institute, 2017). In the USA, the US General Accounting Office was concerned that the enforcement records kept by USDA FSIS were incomplete and that enforcement actions were inconsistent (GAO, 2004). In the next report, it considered that inconsistencies were due to incomplete guidance and inadequate training of inspectors and there was inadequate analysis of enforcement action across districts and plants (GAO, 2010). At that time, the GAO concluded that FSIS could not ensure that it was preventing the abuse of livestock at slaughter plants or meeting its responsibility to enforce the HMSA effectively (GAO, 2010). There are several factors that can potentially result in under-enforcement of legislation (Friedrich, 2015).

Commercial pressure

Regulatory or agency capture is a term used to identify situations where a regulator works very closely with the regulated party with the intention of assisting them in complying, but over time becomes subservient to the industry they are tasked to regulate, with an outcome contrary to the

original policy objectives of the legislation. In this situation, the regulatory authority becomes identified with the regulated industry and facilitates the goals of the industry rather than the legislation. Industry groups can be well organized and devote considerable resources to lobbying government and the regulatory agency to restrict regulatory activity. Where agency personnel either come from the regulated industry or return to it after completing their public service, there is at the very least a perception that enforcement might not be as rigorous as it could be (OECD, 2011, 2014; Whiting, 2013; Friedrich, 2015).

Regulatory ossification can occur where industry lobbying is so unrelenting in its scale and effectiveness that it overwhelms the consultation stages prior to the introduction or revision of regulations that would restrict the industry's commercial activity (Friedrich, 2015). Opponents of legal regulation can also attempt to weaken enforcement agencies by restricting their authority, organizational capabilities and enforcement resources, leading to ineffective enforcement programs (Gray and Scholz, 1993).

Political pressure on a regulatory agency

The leadership of a regulatory agency can be influenced by the commercial pressure from industry that often lobbies government heavily to avoid regulatory enforcement (OECD, 2014). An independent regulatory agency, therefore, provides some protection from political and commercial interests (OECD, 2011). Many regulatory agencies have a management structure that directly influences the scope of the enforcement of regulations by individual inspectors at the plant level and any subsequent action that is taken over reported non-compliance. For an infringement of the regulations to proceed to enforcement action, it will often have to pass through multiple layers of management.

Insufficient funds to conduct enforcement activities

A regulatory agency requires funding for a range of activities, for example to employ sufficient staff, to provide guidance for industry, to train their staff and to undertake enforcement action. Where government does not provide sufficient funding for animal welfare duties and sufficient funds cannot be recovered from industry, there is an obvious

danger of under-enforcement of animal welfare and a focus of scarce resources on food safety (Animal Welfare Institute, 2017; FSA, 2018).

Insufficient time allocated to inspection and enforcement

In the USA, as a consequence of concerns over the balance of resources allocated to animal welfare versus food safety issues, the regulatory agency now records the time that inspectors spend verifying compliance with regulations on handling and slaughter (Humane Activities Tracking System) and there are requirements on the frequency of inspection activities and their predictability in terms of how, where and when inspections are conducted (FSIS, 2011). In England, the Mandatory Use of Closed Circuit Television in Slaughterhouses (England) Regulations, 2018 were introduced to improve the effectiveness and efficiency of the monitoring and enforcement of animal welfare requirements in slaughterhouses. Undercover video evidence had demonstrated major welfare issues in some slaughterhouses. The previous voluntary use of closed-circuit television (CCTV) by the slaughter industry in England had not been comprehensive, in terms of the number of slaughterhouses covered, the areas where CCTV was present and the access to CCTV footage that was provided to the enforcement agency (Farm Animal Welfare Committee, 2015).

Intimidation by slaughter plant

Inspectors can, in some circumstances, be subject to intimidation, violence and harassment. Although most incidents have been reported as having been resolved informally, the enforcement agency may, in extreme circumstances, protect their employees by the withdrawal of inspection and veterinary services (FSA, 2015a).

Types of infringements

A review of non-compliance records issued by FSIS in 2016 (Animal Welfare Institute, 2017) found that the most frequent causes of incidents were:

- lack of worker training in humane handling techniques;
- use of inappropriate stunning devices;
- improper shot placement, often in connection with inadequate restraint;

- lack of routine testing and maintenance of stunning equipment; and
- lack of functional back-up stunning devices.

These findings were similar to the analysis of non-compliance records between January 2001 and March 2003 reported by GAO (2004), in which the most common type of violation was related to ineffective stunning, either as a result of multiple stunning attempts eventually resulting in unconsciousness of the animal, or the animal remaining conscious after stunning. Other non-compliances were caused by poor pen/ground conditions, inadequate access to water and feed, and handling issues related to ‘disabled or sick’ animals, use of excessive force and excessive use of electric prods.

An analysis of FSIS enforcement actions over the period July 2017 to June 2019 (FSIS, 2019b) showed that almost all enforcement leading to either a Notice of Intended Enforcement or a Notice of Suspension of Inspection was due to problems in undertaking effective stunning. The exceptions were handling incidents where, for example, animals were driven over a non-ambulatory animal; or an animal was kicked or hit with a shovel or rod, or died due to entrapment in handling equipment leading to the stunning area, or when an animal broke a leg when it fell from a shackle before ritual slaughter. Enforcement action due to ineffective mechanical stunning was taken when multiple attempts, i.e. more than two shots, were required to achieve unconsciousness. In many cases this appeared to be a consequence of failure to restrain the animal sufficiently, incorrect shot placement on the head, poor maintenance of stunning equipment and ammunition, use of firearms with insufficient power to cause effective stunning, and failure to have a working back-up stunner readily available. In many cases an animal was left too long, i.e. several minutes, in pain and distress between the application of the first shot that caused a penetrating hole in its head and the time that it was stunned successfully. The use of a variety of different firearms and ammunition in the descriptions of enforcement for ineffective stunning was indicative of a lack of knowledge on the suitability of equipment to cause effective stunning, especially of bulls and boars with thick skulls (Atkinson *et al.*, 2013; Whiting and Will, 2019). For pigs, the difficulty in locating the area of the skull over the brain when using captive bolt stunning equipment and firearms to stun pigs (Leary *et al.*, 2016) did not

appear to be appreciated by some establishments. In several cases, pigs were observed to regain consciousness after electrical stunning and sometimes after exsanguination, and slaughter employees did not always recognize this. As identified by the Animal Welfare Institute (2017), the HMSA and associated regulations and directives do not contain the same types of requirements for training and assessment of competencies as those contained in, for example, Council Regulation (EC) No. 1099/2009. There is also no specific requirement for appropriate back-up stunning equipment to be immediately available and used if the original stunning equipment fails.

A review of audits conducted by the European Commission’s Food and Veterinary Office (FVO, 2015) identified the following compliance issues with the EU regulation on slaughter (Council Regulation (EC) No 1099/2009):

- lairage capacities sometimes exceeded;
- lack of feeding or bedding for animals after more than 12 h in the lairage;
- some animals unfit for transport arriving for slaughter;
- inadequate documented procedures for assessing loss of consciousness after stunning; and
- inadequate electrical stunning of poultry.

Published data on enforcement action by the FSA in the UK following non-compliance with regulations (Table 17.1) provide examples of the types of issues recorded by inspectors and what action was taken. However, this data might not provide useful information on the prevalence of welfare issues. The high level of compliance might, of course, be due to the UK slaughter industry undertaking near-perfect operations. However, other evidence suggests that welfare issues still occur at slaughterhouses. The low number of recorded events might be due to a range of issues, such as problems with a central database, lack of standardized recording methods, inspectors not recording their observations, not undertaking inspections in areas of the slaughterhouse where non-compliance occurs, or not undertaking inspections at an appropriate time or for sufficient duration. The types of welfare issues recorded are affected by the specific legislation in the UK, the training and direction provided to the inspectors by the management of the enforcement agency, the species and local factors, such as the thermal environment, and methods of transport, handling and slaughter. In 2011, a 1-week assessment

Table 17.1. UK Food Standards Agency data on the number of records of non-compliance with slaughter regulations 2017–2018 (FSA, 2019a).

		Type of animal			
		Cattle	Pigs	Poultry	Sheep and goats
Area of slaughterhouse	Unloading	13	2	12	1
	Lairage	35	27	23	75
	Movement and restraint	22	12	97	28
	Stunning	59	19	37	34
	Bleeding	3	5	33	13
Management responsibilities for compliance such as up to date Standard Operating Procedures		44	10	49	54
No. of animals affected by non-compliance		822	358	20,439	6,009
Throughput during period of recording (no. of animals slaughtered)		3,560,142	17,435,960	1,997,819,000	26,272,949
Enforcement action	Verbal advice	115	47	104	121
	Written advice ^a	57	30	107	77
	Welfare enforcement notice	26	5	56	44
	Referred for further investigation and potential prosecution	11	5	63	14

^aLetter outlining issues with compliance and requesting correction of issues

of 328 establishments in Great Britain reported that 99% were fully compliant, or only demonstrated minor deficiencies with the requirements of the slaughter legislation (FSA, 2012). The minor deficiencies included: no back-up stunner available; no water available for pigs; and overcrowding. Major deficiencies included: entrapment in a pen; no water available for pigs kept overnight; and inadequate bleeding of poultry. Further details were provided in a survey conducted in 2013 of inspectors' assessments on compliance with various aspects of the regulations (FSA, 2015b).

The UK Food Standards Agency (FSA) published detailed records of non-compliance with animal welfare regulations for the slaughter of animals between April 2011 and March 2014 (FSA, 2017). An analysis of these records showed that considerable attention was given to welfare issues associated with the handling and transport of broilers to slaughter. Many of these issues were related to injuries from poor handling, birds not in an upright posture, trapping of live birds, and overcrowding in crates and modules. Poor transport conditions resulting in heat stress and inadequate ventilation or cold stress from inadequate protection from rain and cold weather were associated with incidents where the prevalence of dead-on-arrivals exceeded normal thresholds. The inspectors recorded many incidents where the prevalence of breast blisters,

hock burn and foot pad dermatitis indicated poor on-farm conditions. Several incidents were caused by poor lairage management. These included loose birds, inadequate ventilation and live birds wetted from spray from pressure hoses or from passing through the crate wash. There were some incidents of poor shackling practices, with some birds left too long inverted in the shackles before stunning. There was a relatively small number of events recorded where the stunning equipment was not operated correctly, for example the level of water in the electric stunner bath was too low, or the current was too low. Some birds received pre-stun electrical shocks, some were not properly stunned, and one bird was drowned in the water-bath. There were many events where the neck-cutting equipment was not operated effectively and many birds were either not cut or were bled poorly. Inadequate performance or competency of slaughtermen was recorded as an issue. Almost half of the incidents were dealt with by offering verbal advice; written advice was provided in 3.5% of events; 14% were referred to management for further action; and 34% were referred to the regulatory authority responsible for the enforcement of transport and on-farm regulations. In the 102 events recorded where there was evidence of avoidable pain, distress or suffering during stunning or killing, 87% were dealt with by offering verbal advice, written advice was provided

in 8% of events and 4% were referred to management for further investigation.

For cattle, most of the recorded events related to transport to slaughter and were associated with: transport in late pregnancy; injury; lameness; non-ambulatory, weak and blind animals; and overcrowding. Issues related to poor on-farm management included in-growing horns, overgrown hooves, emaciation, abscesses and tumours. For cattle, most of the recorded events for lairage management were due to failure to provide clean drinking water and feed, inadequate or no bedding, and overcrowding in pens. Handling issues recorded were delays in the race and stunning box, injuries and inappropriate use of goads and sticks. Some poor handling methods and the escape of cattle were recorded. Inadequate or no head restraint for stunning was recorded. In the 89 events recorded where there was evidence of non-compliance during stunning or killing, most of the events were related to inadequate stunning, too long a period between stunning and exsanguination, and too short a period between exsanguination and dressing. Other recorded events included an absence of back-up stunning equipment, no slaughter licence, and inadequate maintenance of captive bolt and electrical stunning equipment. In the 13 events recorded where there was evidence of avoidable pain, distress or suffering during stunning or killing, ten were dealt with by offering verbal advice and written advice was provided in the other three events.

For pigs, most of the recorded events related to transport to slaughter and were associated with injuries (including tail bites and slap marks), lameness, transport in late pregnancy and conditions affecting fitness for transport, including prolapses and hernias. Issues related to poor on-farm management were emaciation, overgrown hooves and abscesses. For pigs, most of the recorded events for lairage management were due to failure to provide clean drinking water, risk of injury from poor maintenance of equipment, overcrowding in pens and inadequate lighting. Many events were due to poor handling, including dragging by ears or tails and excessive slapping. For pigs, most of the issues of non-compliance during slaughter were due to inadequate display of the current applied during stunning, ineffective stunning, lack of back-up stunning equipment, lack of slaughter licence, delays in exsanguination after stunning and live pigs entering the scalding tank. None of the events where a live pig entered the scalding tank or when

the ears were removed before bleeding was completed was considered by the inspectors to demonstrate evidence that the pigs suffered any avoidable pain, distress or suffering during killing, i.e. they were coded as a score 3 (potential risk to welfare), and only verbal or written advice was provided.

Conclusions

Slaughter legislation to protect the welfare of animals remains a controversial topic. There are divergent views on its necessity and effectiveness in enhancing animal welfare. This chapter has argued the merit of legislation to protect animals during slaughter in that slaughter is a process where animals are at risk of suffering, and they benefit from the external oversight that legislation provides. There are close relationships between the regulation of animal welfare and food safety within slaughterhouses. The evolution of regulatory policies has influenced the approach to slaughter legislation. Within legal regulations, responsibility is placed on the slaughterhouse operator to develop internal policies and procedures to mitigate animal welfare risks and monitor outcomes so that they can take corrective action as soon as a problem is identified. The role of the regulator has expanded from an enforcement role to one that facilitates and cooperates with the operator to achieve compliance with regulations and reduce risks to animal welfare. Emphasis is placed on the verification of procedures and corrective actions undertaken by the slaughterhouse. There are challenges in enforcing slaughter legislation and it is difficult to assess the effectiveness of enforcement. Reports provided by enforcement agencies indicate that compliance with legislation is high. Although there is independent evidence that standards in slaughterhouses have improved, critics suggest that improved inspection and enforcement would show that there are major issues that still need to be addressed. Reports on the types of infringements of regulations that occur indicate the continued need for legislation and in some cases revision of current regulations. Many of the welfare issues described could be addressed by more training and by dissemination of current knowledge and understanding of best practice.

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18 Ethical Issues: Introduction to Chapters 18a–e

TEMPLE GRANDIN

Department of Animal Science, Colorado State University, USA

It is important for people in the meat industry to understand different ways that people outside the industry view the use of animals for food. There are five short sub-chapters in Chapter 18. Two contributions discuss the ethical importance of good animal welfare and why it must be taken seriously.

Two other contributors discuss ethical reasons for not eating meat, from the viewpoint of animal rights and animal protection. Another chapter discusses the value of meat in the diet and methods such as improved grazing that can mitigate environmental problems.

18a

Animal Rights Viewpoint: The Abuse of Animals Won't Stop Until We Stop Eating Meat

PETER SINGER

University Center for Human Values, Princeton University, USA

(Reprinted with permission from Peter Singer, *The Guardian*, 11 February 2015.)

Forty years after I wrote Animal Liberation, it's easy to think little has changed: but attitudes to the meat-eating industry, and our speciesism, are changing.

When *Animal Liberation* was published, I hoped that, 40 years on, there would be no more slaughterhouse – and therefore, no more newspaper stories about atrocities like the one at an abattoir in the north of England. The arguments against our oppression of animals seemed to me so clear and irrefutable that surely a powerful movement would arise, consigning these abuses to history, as the anti-slavery movement had put an end to the African slave trade.

At least, that is what I thought in my optimistic (or naïve) moments. In my more pessimistic (or realistic) moments, I understood the vastness of the task of changing habits as deeply ingrained as eating meat, and transforming philosophical outlooks as fundamental as speciesism.

More than 200 years after the abolition of the slave trade, racism is still with us, and even slavery, though everywhere illegal, still exists. How could I expect ending speciesism and animal slavery to be easier or more swift than ending racism and human slavery?

Against the background of those more realistic assumptions we can deplore the fact that animals are still being mistreated on a vast scale, but we should not despair. In many parts of the world, including Europe and the US, there has been tremendous progress in changing attitudes to animals.

A powerful animal advocacy movement has emerged, and it has made a difference for billions of animals.

In 1971, when a few other students and I set up a display in Oxford to show passers-by how their eggs and veal were produced, people asked if we really imagined that we could win against the political and financial might of the agribusiness industry. But the animal movement has challenged that industry with success, achieving reforms across the entire European Union that require farm animals to have more space and better living conditions, and similar changes have now become law in California as well. Admittedly, these changes are still far from giving factory-farmed animals decent lives, but they are a significant improvement on what was standard practice before the reforms came into effect.

Perhaps even more satisfying is the number of people who have abandoned eating animals entirely, and the others who have cut down their meat consumption for ethical reasons. In the 1970s, to be a vegetarian was to be a crank – a thought reflected in the self-mocking name of what was then London's best vegetarian restaurant, Cranks. If you used the term 'vegan' you invariably got a blank look and had to explain what it meant.

Despite all this, it is probably still true that there are more animals suffering at the hands of humans now than ever before. That is because there are more affluent people in the world than ever before, and satisfying their demand for meat has meant a vast expansion of factory farming, especially in China. But to see this as an indication that animal advocates have made no progress would be like saying that because there are more slaves in the world now than

there were in the 1800s, the anti-slavery movement has made no progress. With the world's population now more than seven times what it was in 1800, numbers do not tell the whole story.

Progress is not steady. There will always be periods in which we seem to be treading water, or even going backwards. Periodically articles appear about the resurgence of fur, for example, but I doubt that fur will ever be as uncontroversially accepted as it was 40 years ago. The fact that newspapers give extensive coverage to stories about the abuse of animals being slaughtered for food (not only about abused dogs, cats or horses) is itself a sign of progress.

Meanwhile, there is a simple lesson to draw from the videos released by Animal Aid investigators: if you turn animals into things to use, and give workers complete control over them, it will never be possible to stop the occurrence of the kind of abuse allegedly shown in the videos. Sacking one or two workers merely makes a scapegoat out of them. (Think about what that word tells us about our traditional attitude to animals.) The problem is not one or two workers, nor the practice of halal slaughter, but the system, and the system will not change until people stop buying meat.

18b

Ethical Defence of Eating Meat: The Place of Meat Eating in Ethical Diets

FRÉDÉRIC LEROY^{1*}, MIKI BEN-DOR², FRANK M.
MITLOEHNER³

¹*Industrial Microbiology and Food Biotechnology (IMDO), Faculty of Sciences and Bioengineering Sciences, Vrije Universiteit, Brussels, Belgium;* ²*Department of Archaeology and Ancient Near Eastern Cultures, Tel Aviv University, Israel;* ³*Department of Animal Science, University of California, Davis, USA*

Summary

Meat can be part of an ethical diet. The inclusion of animal produce in the diet offers nutritional robustness, especially in vulnerable populations. This is part of the ethical justification of meat eating. The ecological argument against meat eating needs to be put in perspective. Improved grazing methods can improve biodiversity and topsoil formation. A vegan society could lead to disastrous monocropping.

Learning Objectives

- Role of meat in a healthy diet.
- Meat is key part of early human diets.
- Learn how livestock can mitigate ecological damage.
- Learn about problems with a vegan world view.

Introduction

Despite its longstanding rank as a health food, meat is now often represented as intrinsically harmful to humans, animals and the planet (Leroy, 2019). This shift is due to three intertwined narratives that relate its consumption to disease, ecological dam-

age and animal welfare issues. The evolution is partially driven by honest concern, scientific opinion and dietary guidelines, which are not free from bias and inconsistency (Ioannidis, 2018), and propagated by mass media, ideologists and vested interests in a post-truth setting (Leroy *et al.*, 2018a). Whereas meat's expanding production is sometimes blamed on agri-food lobbying (GRAIN/IATP, 2018), an increasingly popular plant-based market is in its turn supported by various investors and food processors (Murphy, 2018). Coupled with a deceptive health discourse, the ultra-processing of low-priced materials (e.g. corn, soy, oil) into meat imitations generates profit margins that are not achievable with raw materials and fresh foods. Attributing symbolic value to products of inferior quality via (lifestyle) branding is how industry exploits a consumerist need to accumulate 'cultural' capital (Baudrillard, 1970; Ulijaszek *et al.*, 2012). The public debate is therefore polarized and prone to manipulation by various agendas, including ideological ones (Banta *et al.*, 2018). In this chapter, the three above-mentioned narratives (i.e. health, planet and animals) will be critically assessed. Moreover, it will be argued that there is (and should be) a prominent place for livestock and meat traditions within ethical worldviews.

* Email: Frederic.Leroy@vub.be

Meat Eating Brings Health and Nutrients, Not Disease

It is commonly stated by health institutions (e.g. IARC, 2015; WHO, 2015; NHS, 2018) and in academic literature that meat eating is related to increased mortality (Larsson and Orsini, 2014) and the development of cardiometabolic diseases (Pan *et al.*, 2011; Abete *et al.*, 2014; Yang *et al.*, 2016; Kim and Je, 2018), cancers (Huang *et al.*, 2013; Carr *et al.*, 2016) and intestinal illness (Cao *et al.*, 2018). Extrapolation of such data to causal interpretations and explicit dietary guidelines is nevertheless unsound (Alexander *et al.*, 2015; Klurfeld, 2015; Feinman, 2018; Leroy *et al.*, 2018b). Meat's relative risk (RR) levels obtained from epidemiological studies are generally much below two, far beneath what is reported for true risk factors. Compare, for instance, how excessive visceral fat generates an RR of 5.9 for colorectal cancer (Yamamoto *et al.*, 2010), whereas for red meat this value is below 1.2. The latter RR levels would be unacceptable as proof in most epidemiological research outside nutrition (Shapiro, 2004; Klurfeld, 2015), especially considering the profusion of false-positive results and the large bias and uncertainty in the datasets (Bofetta *et al.*, 2008; Young and Karr, 2011). Particularly problematic are the use of food frequency questionnaires (Archer *et al.*, 2018; Feinman, 2018) and the poor disentanglement from other lifestyle factors associated with Western-style meat eating, such as low-quality diets, obesity, smoking and limited physical activity (Alexander *et al.*, 2015; Fogelholm *et al.*, 2015; Wang *et al.*, 2016; Grosso *et al.*, 2017; Turner and Lloyd, 2017; Hur *et al.*, 2018). These problems are reflected in the fact that observational claims from nutritional epidemiology are commonly dismissed or even refuted in randomized controlled trials (RCTs) (Young and Karr, 2011), as shown for meat as well (Turner *et al.*, 2015; O'Connor *et al.*, 2017). Moreover, RCTs are not necessarily unproblematic either (Krauss, 2018). Transposition of results from intervention studies to actual risk level can be questionable, as RCTs looking into meat intake do not consider normal dietary context and rely on poor biomarkers (Turner and Lloyd, 2017; Kruger and Zhou, 2018). Also, evidence is usually cherry-picked, so that conflicting data is simply ignored. Inconvenient examples include the multiple studies where meat avoidance is not (or even positively) associated with mortality and disease (e.g. Key

et al., 2009; Burkert *et al.*, 2014; Iguacel *et al.*, 2019; Okuyama *et al.*, 2018; Yen *et al.*, 2018).

Not only is the evidence to incriminate meat inadequate, but also the latter deserves reappraisal as a key element of our species-adapted diet (cf. Cordain *et al.*, 2000; Stanford and Bunn, 2001; Leroy and Praet, 2015; Gupta, 2016). The appearance of *Homo*, 2.5 million years ago (Mya), parallels the emergence of stone tools and animal bones in archaeological sites (Pante *et al.*, 2018), intensifying after the rise of *Homo erectus* some 1.9 Mya (Pickering and Domínguez-Rodrigo, 2010; Domínguez-Rodrigo and Pickering, 2017). Increased reliance on animal food, at the expense of fibrous plants, explains such adaptations as increased body and brain size and reduced mandible and teeth size (Aiello and Wheeler, 1995; Stanford and Bunn, 2001). Continuous signs of preference for the hunting of large animals (Broughton *et al.*, 2011; Speth, 2012) and the punctuated extinction of large carnivores, but not of medium-size or small ones, around 1.5 Mya, suggests that *Homo* took a prominent position in the large carnivore guild (Lewis and Werdelin, 2007; Werdelin and Lewis, 2013). Whereas reliance on animal foods appears throughout the Pleistocene (Stiner, 2002; Richards and Trinkaus, 2009; Balter *et al.*, 2012), signs of increasing plant eating emerge gradually starting about 0.04 Mya at the Upper Palaeolithic (Kuhn and Stiner, 2001). The latter culminated in the transition to plant domestication at 0.01 Mya, which paralleled the domestication of livestock in most regions (Vigne, 2011). Physiological and life-history phenomena further indicate human reliance on animal foods throughout evolution. Unlike herbivores and omnivores, the human stomach is among the most acidic in the animal kingdom (Beasley *et al.*, 2015), which protects humans from meat-borne pathogens and is typical of carnivores and scavengers. Also, human fat tissue has a cellular structure, which is typical of carnivores. 'These figures suggest that the energy metabolism of humans is adapted to a diet in which lipids and proteins rather than carbohydrates, make a major contribution to the energy supply' (Pond and Mattacks, 1985). A comparison of the age at weaning of herbivores, omnivores and carnivores highlights the 'emergence of carnivory as a process fundamentally determining human evolution' (Psouni *et al.*, 2012). Earlier age at weaning is made possible by the replacement of maternal milk with the high nutrition density of meat and fat (Kennedy, 2005).

This brief review of the archaeological and physiological signatures of meat consumption underlines that it has been a key part of human nutrition during the past 2.5 million years. On an evolutionary basis, meat has thus been delivering valuable nutrients, of which some are not easily obtained from plants (Pereira and Vicente, 2013; Young *et al.*, 2013; McNeill, 2014; Leroy *et al.*, 2018b). This is in particular the case for essential amino acids (lysine, threonine and methionine being in short supply in plant-based diets), long-chain omega-3 fatty acids (EPA/DHA), B vitamins (of which vitamin B₁₂ is limited to animal products only), vitamins A and K₂, and minerals such as selenium, zinc and iron. Other components that may be suboptimal without meat include taurine, creatine and carnosine. Including meat in the diet is particularly meaningful to prevent deficiencies in young females (Fayet *et al.*, 2014), to improve the thriving and cognitive development of infants and children (Hulett *et al.*, 2014; Tang and Krebs, 2014; Cofnas, 2019) and to prevent or treat malnutrition and sarcopenia in the elderly (Shibata, 2001; Phillips, 2012; Rondanelli *et al.*, 2014). Avoidance of animal products can result in malnutrition (Ingenbleek and McCully, 2012) and deficiencies (Wongprachum *et al.*, 2012; Foster *et al.*, 2013; Pawlak *et al.*, 2014; Woo *et al.*, 2014; Brantsæter *et al.*, 2018; Naik *et al.*, 2018). Furthermore, it is associated with depression and eating disorders (Zhang *et al.*, 2017; Barthels *et al.*, 2018; Hibbeln *et al.*, 2018) and may lead to neurological problems (Kapoor *et al.*, 2017). Taken together, the fact that inclusion of animal products in the diet offers nutritional robustness, especially in vulnerable populations, is part of the ethical justification of meat eating.

Livestock Is Part of the Solution for the Mitigation of Ecological Damage

The ecological argument against meat eating equally needs to put in perspective (Fairlie, 2011). It is commonly assumed that the farming of livestock *as such* is too water- and land-intensive and therefore wasteful. First, 87% of the water used by livestock is green water originating from rainfall, which in the case of grazing beef equals 94% (Mekonnen and Hoekstra, 2010). With respect to land use, the debate needs to bear in mind that a quarter of the global agricultural area consists of non-convertible pastures and rangelands (1.3 billion ha) (Mottet *et al.*, 2018) also referred to as ‘marginal land’. Although the

option of rewilding should not be overlooked, exclusion of livestock from food production would leave marginal land that, in the context of food production, can only be dedicated to ruminant grazing, as unexploited. This is also primordial for rural development, as livestock in such areas contribute to the livelihoods and nutritional security of millions of farmers (430 million out of 729 million poor people in rural and marginal areas are livestock farmers; FAO, 2020), as well as the empowerment of women (Mottet *et al.*, 2018). Livestock provide high-quality nutrition, asset savings, traction and manure nutrients for use as fertilizers in regions where cropping is problematic. The argument that animal feed competes with crops directly suitable for the human diet is partially true but also needs nuance. Contrary to overblown estimates of 6–20 kg grain per 1 kg meat, the actual number is close to 3 kg (Mottet *et al.*, 2018). Additionally, 86% of livestock feed is not suitable for human consumption, consisting of forage as well as crop residues and by-products that otherwise would represent an environmental burden. For ruminants, only 5% of the feed directly competes with human food (mostly grain and some soybean meal) (Mottet *et al.*, 2018). Cattle thus contribute to global food security, as they need only 0.6 kg of human-edible feed protein to produce 1 kg of animal protein, which has a higher biological value and makes them net contributors to global human-edible protein production (Mottet *et al.*, 2017, 2018; FAO, 2018).

With respect to climate change, livestock are said to generate 14.5% (7.1 gigatons CO₂-eq per year) of the total greenhouse gas (GHG) emissions, largely because of feed production (45% of contribution; including deforestation) and enteric fermentation by ruminants (39%) (Gerber *et al.*, 2013). This is worrying but needs contextualization. First, the metric viewing ruminant-derived methane as many times more harmful than CO₂ is unjustified, because atmospheric stabilization of the latter can only be obtained upon a massive reduction (80%) compared with a smaller drop of the former (30%) (Fairlie, 2017). Second, the 14.5% number reflects vast regional heterogeneity. In the USA, direct livestock GHG emissions from manure and enteric fermentation account for only 3% of the anthropogenic GHG emissions, far below the 26% of CO₂-eq by the transportation sector (Place and Mitloehner, 2012). Therefore, a global mitigation of 30% and more might be achieved if the practices of the 25% most efficient producers were to be adopted worldwide,

especially with respect to ruminant systems with low productivity in Latin America, sub-Saharan Africa and South Asia (Gerber *et al.*, 2013). Additionally, better grazing land management has the potential to offset emissions via grassland carbon sequestration (Gerber *et al.*, 2013; Teague *et al.*, 2016; Stanley *et al.*, 2018). Grazing plays a role in ecosystem shaping, whereby ruminants take over the role of wild herbivores, manure-fertilize cropland and grassland, and improve biodiversity and topsoil formation. Yet, to be able to benefit from the potential assets of livestock management, interventions will be needed through further productivity improvements, adjustment of grazing pressure to improve carbon sequestration and build topsoil, and better integration in the circular bioeconomy (e.g. enhancing the use of by-products) (Mottet *et al.*, 2018). Larger shifting of ruminant grain feeding to grazing and improved channelling of waste streams to efficient conversion by pigs and poultry hold important potential (Fairlie, 2011).

To sum up, and as stated in the FAO report by Gerber *et al.* (2013), ‘the livestock sector *should* be part of any solution to climate change’ (our emphasis). Although there are reasons to consider a reduction of livestock numbers, its elimination would be unwise. A vegan society could easily lead to disastrous monocropping, driven by fossil fuel-derived fertilizers and resulting in topsoil depletion and biodiversity losses. Grass would need to be kept down with herbicides in the absence of grazing, and by-products of cropping would be left to waste (Fairlie, 2018). In the West, it would reinforce reliance on the import of crops (e.g. soy, bananas, coconuts, rice) and the formation of apocalyptic greenhouse landscapes (as currently found in Almeria) (MailOnline, 2013). A first priority in reducing climate change contributors should be in the drastic reduction of fossil fuel use and the associated rapid extraction of carbon deposits, which needed millions of years to accumulate (Fairlie, 2017).

Vegan Ideology Leads to Problematic Worldviews

Human–animal interactions, either through hunting or livestock keeping, have been fundamental to our biosocial development (Leroy and Praet, 2015). The heavily ritualized and culturally entrenched relationship with animals, although intimately linked to killing for food, has been driving the very evolution of our species. When not seen all too anthropocentrically, it can even be valued as a rich and symbiotic

association between humans and animals. In contrast to ferocious life in the wild, humanely kept livestock animals are (or should be) receiving a decent life, feed during winter and a fast death. According to Baggini (2014), it is not against livestock’s *interests* or *nature* to be farmed, nor is there a good reason to deny that farming can provide a good life. Moreover, the number of sentient beings killed during crop harvesting or for pest control likely exceeds the death toll of animal husbandry per unit of food (Davis, 2003; Archer, 2011), although numbers are uncertain (Fischer and Lamey, 2018). Refusing to eat meat points toward an alienated relationship with nature and a failure to grasp the dynamics of life and death, which seems typical for the Western urban mindset (Fairlie, 2018). Whilst traditional societies, in particular hunter-gatherer groups, display a respectful attitude toward animal killing (Leroy and Praet, 2017), vegan belief often refers to a biocentric Garden-of-Eden concept (Sánchez Sábaté *et al.*, 2016), with death being a ‘contaminant essence’ (Testoni *et al.*, 2017). In such worldview, a strict nature/culture compartmentalization would be required, by fencing off crop production from wildlife to avoid the otherwise necessary killing of vermin. To eliminate animal killing altogether, vegan ideologists may even consider intervening in wildlife (i.e. *within* the nature side of the binary), for instance by pursuing genetic engineering of carnivores into herbivores or by phasing out wildlife populations via sterilization and confinement of the remaining animals to parks (Moen, 2016). It may even be preferable to some vegans to have no animals at all, rather than have them subjected to a nature that is red in tooth and claw (Moen, 2016). Considering that some theorists are in favour of legally imposing veganism on society at large (e.g. Deckers, 2013), such ideas are alarming indeed.

Conclusions

There are issues of concern related to current animal production systems that will need to be addressed on a global level. Yet, the historically unprecedented societal stigmatizing of meat eating as being severely detrimental to humans, animals and the planet is astonishing. Meat as such *does* hold a main place in ethical dietary behaviour, although there is margin for correction and improvement of its aspects of healthiness, sustainability and animal welfare. This may or may not mean that less meat should be consumed, produced by more suitable

livestock management and with increased attention for animal welfare criteria, but certainly not that meat should be *avoided*. Meat has to be credited for being at the basis of our wider biosocial evolution, as it is a nutrient-dense key element of our species-adapted diet and has contributed to both our biological and behavioural idiosyncrasies, including its rich influence on cultural heritage and livelihoods. This is also valid for livestock since Neolithic times and, more broadly, for human–animal interactions going back to our earliest existence as hunter-gatherers. Properly organized and animal-friendly livestock management may not only reduce environmental impact but may even be part of the solution to mitigate climate change. A switch to a meat-free world would represent a reinforcement of the problematic nature/culture binary and a mass experiment of unknown proportions, of which the outcome is not only unpredictable but also leading to its own set of ethical concerns.

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18c

Animal Welfare Viewpoint: Why Should Industry Worry About Food Animal Quality of Life?

BERNARD E. ROLLIN

Department of Philosophy, Colorado State University, USA

Summary

Animal agriculture often has resistance to public scrutiny. A CEO of a major European swine company said that the agricultural industry must listen to society because they can shut it down. Sound science is not sufficient to fully understand animal welfare. An animal can be productive and have poor welfare because its *Telos* or natural behaviours cannot be performed. The industry has a choice. It can either self-regulate or face an uncertain future. Societal changes such as the rise of artificial meat and the demise of animal exhibitions and circuses may be a harbinger of where society is heading. If the animal industry fails to acquiesce to the demands of society, it may be forced to do so.

Learning Objectives

- Make the reader see a perspective that is outside the meat industry.
- Sound science is not a substitute for ethics.
- The animal industry must not ignore societal demands.

Introduction

I am often asked by my cattle-producer friends why they should have to listen to members of the general public regarding animal welfare when the public knows virtually nothing about animal production; what the public 'knows' is often grossly wrong or misinformed; and producers themselves are the true experts concerning animal welfare. The best response to this query I have encountered came from a commentary by the CEO of a European swine company. What he said in essence was the

following: 'Why listen to society in general? Because they can close you down tomorrow!'

His response contains two elements. First, in a democracy, the general public can dictate policy through the political process even regarding things they do not understand. Second, and equally devastating, the public can refrain from buying your product.

Regarding the first element, in my work on animal research I have seen this happen repeatedly. In the early 1980s, I was invited to Australia to help facilitate a political dialogue on the regulation of animal research. Historically, all over the world, the research community has been extremely resistant to public accountability. Among the options being considered by the Australian Senate was a complete ban on any animal research in Australia, a point stressed by the chairman of the relevant Senate committee. The fact that that did not occur was largely due to the presence of a robust approach to regulation of animal research suggested by me that was in fact adopted, what one sociologist referred to as 'enforced self-regulation'.

A very similar pattern occurred in the USA. When I was pressing for oversight of animal research by institutional animal care and use committees in the early 1980s, there was also well-supported legislation advanced that would have cut the multibillion-dollar federal research budget by up to 60% and directed the money towards creating alternatives to animal use. (When I asked the woman responsible for the bill what she meant by 'alternative', she replied, 'Oh you know, a plastic dog that howls when you cut it and bleeds ketchup!') Public support for animal research has been steadily declining and the research community

is seriously discussing increasing transparency (Foundation for Biomedical Research, 2018).

Similar moves have also occurred with US agriculture. Many consumers have put their dollars into purchasing organic animal products, under the mistaken belief that organic entails good animal welfare. This is demonstrably false, as I have shown in writing. For example, when organic rules forbid the use of antibiotics for treating painful afflictions like foot rot, the animals suffer considerably more than if antibiotics had been deployed.

To understand the claim that the US public will support animal production if they are convinced that the animals live under conditions assuring a good quality of life, one must first understand some basic features of ethics. Ethics may be divided into three categories: personal ethics; societal ethics; and professional ethics. Personal ethics are the individualized rules by which a person determines what they believe is right and wrong. A moment's reflection reveals that diverse personal ethics fail to assure the possibility of a functional and robust society. The reason, as Thomas Hobbes pointed out, is that one ends up with variegated individual ethics, virtually assuring 'a war of each against all', a state of chaos and anarchy.

Societies Have a Consensus Ethic

The only way to avoid this is to create a relatively strong societal consensus ethic that everyone is obliged to obey. Even in US democratic society, driven in principle by a major commitment to individual freedom, there exist strict ethically based laws against robbery, murder, sexual assault, child abuse and other actions that compromise the ability of individuals to live a decent life. In fact, one way to assure the loss of freedom is to flagrantly violate societal ethical principles and concerns.

Professions are subgroups of society that are given the job of performing tasks of great importance and requiring specialized training, education and skill. Medicine, veterinary medicine, accounting and law are paradigm cases of professions. Professions are allowed to regulate themselves as long as their rules of self-regulation are consonant with societal ethics. Society in essence says to professions, 'You regulate yourselves the way we would regulate you if we genuinely understood what you do and what it takes to do it.' If a profession violates societal expectations, it risks being regulated by people who do not understand how it operates.

The draconian rules governing accounting in the wake of numerous scandals is an excellent example of how this occurs.

There is ample evidence of great societal concern about animal welfare across the world regarding all animal use. Understanding this is absolutely essential to anyone in animal agriculture. One can see this all across the Western world. For example, the demise of killer whale shows at Sea World and the end of the 125-year reign of Ringling Brothers circus, in spite of the love the public has previously had for animal shows, eloquently bespeaks what is happening in society, as does the regulation of animal research over the past three decades, despite the research community's threats to society that any regulation will impair human health. Also attesting to this is the tight legislative control on animal agriculture in Europe.

Ethics and Animal Welfare

Unfortunately, people in animal-using areas, particularly agriculture, lack full understanding of the concept of animal welfare. It is generally seen as strictly a matter of 'sound science' in both agriculture and veterinary medicine. There is no doubt that there is a scientific component to animal welfare. One certainly needs to know a fair amount about the animals' needs and natures in order to address them. But one can never forget that, in the context of human use of animals, the concept of animal welfare entails an ethical decision on what we owe animals and to what extent. In the early 1980s, the agricultural community produced a document known as the *CAST Report*, addressing animal welfare. In that report, it was argued that all we owe animals is what it takes to get them to be maximally productive (CAST, 1981). Clearly, any ethical component therein was totally self-serving.

In contradistinction, the Farm Animal Welfare Council (FAWC), a British committee that grew out of the Brambell commission, chartered by the British government to investigate farm animal welfare, defined animal welfare in terms of the famous *Five Freedoms* (www.fawc.org.uk).

1. **Freedom from Hunger and Thirst** – by ready access to fresh water and a diet to maintain full health and vigour.
2. **Freedom from Discomfort** – by providing an appropriate environment, including shelter and a comfortable resting area.

3. **Freedom from Pain, Injury or Disease** – by prevention or rapid diagnosis and treatment.
4. **Freedom to Express Normal Behaviour** – by providing sufficient space, proper facilities and company of the animal's own kind.
5. **Freedom from Fear and Distress** – by ensuring conditions and treatment which avoid mental suffering.

The ethic implicit in the FAWC definition could not be more different than what is in the Cast Report.

Lessons from Ancient Philosophies

Since there is a wide variety of ethical positions on human moral obligations to animals, there is also as wide a variety of definitions of animal welfare. The obvious question that arises is this: whose definition of animal welfare will and should prevail? Will it be the industry definition, that of advocates for animal welfare, or something else?

In order to answer this question, we can borrow an account of general human obligations from the ancient philosophers known as the Stoics (Inwood, 2003). This account is as applicable today as when it was formulated in ancient times. For those among us who are not moved by moral arguments, there exists an undeniable argument from self-interest. In their account of the nature of human life, the ancient Stoic philosophers articulated a powerful metaphor that admirably fits the requirement that we all act in accord with societal ethics. Paraphrasing them, social ethics can be schematized as an oxcart on its way to a nearby town. You are chained to the oxcart. You have two choices: you could dig in your heels and resist, in which case you will arrive at the town broken and bleeding. Or you could walk when the oxcart walks, rest when it rests, in which case you will be unscathed.

Dealing with ethical issues raised by your activities is very much analogous to the Stoic point. It is far easier to self-regulate and do the right thing than to wait for society to impose it upon you. You understand your own activities far better than society does. You are far more concerned with preserving your freedom of action than the rest of society is. And most important, you understand what can practically be done without imposing great harm on the regulated area. In most cases, society wants to see a problem solved and will impose a putative solution with a heavy hand. Self-regulation, if permitted, will accomplish far more in a far less onerous manner. The emergence of an industry devoted to creating 'artificial

meat', in which even meat companies are investing, is a harbinger of where society may turn if the animal industry fails to acquiesce to the demands of society.

Agriculture Must Not Ignore Societal Demands

I can provide a vivid personal example of what can happen if the agricultural industry disregards these demands. Last year, I was visited by a very well-known animal activist seeking my support for a new campaign. Although she was better informed than most about the beef industry, what she wanted to accomplish was thoroughly impractical. She was concerned about unusually snowy winters where animals out on range had no access to shelter. She wanted ranchers to set up shelters at regular intervals wherein animals could escape from the snow. If ranchers failed to do this, on her plan they would lose federal reimbursement for cattle that died under snowy conditions.

Using North Dakota as an example, I asked her if she had any idea of the size of a large North Dakota ranch. She did not. I explained to her that ranches in North Dakota can easily exceed 100,000 acres. I also explained to her that one could not know in advance where such shelters were needed. Snow accumulation varies with the wind and a place requiring shelter one year might not need it the next. I also conveyed to her that of all contemporary agriculturalists, ranchers undoubtedly had the greatest concern for their animals.

To evidence my point, I told her about the statue that stands in front of the agriculture building at Colorado State University. Entitled '20% chance of flurries', it depicts an elderly rancher on horseback carrying a lost calf across the saddle in the middle of a snowstorm. Realistically rendered, even showing his windblown duster and white snowdrifts, it eloquently bespeaks the rancher ethic, with the cattleman risking his life to bring home the baby animal. Clearly, his motivation is not financial. I advised her to drive to ranch country to see how impracticable her suggestion was. To her credit, she was willing to learn. I also pointed out to her that it was precisely her kind of concern about leaving animals under natural conditions that led to the kind of high-confinement agriculture she despised. This is an excellent example of societal ignorance underlying good intentions.

Returning to our main point: if the concept of animal welfare irreducibly involves animal ethics,

whose ethics will determine the relevant concept of animal welfare? And the answer is: those of society in general and those of the consumer. We have already seen changes in such practices as raising veal in crates mandated by consumer concern.

Here is a personal example of how this works. In 2008, I was approached by Smithfield Farms, the largest pork producer in America, for advice on managing societal animal welfare concerns. I told them that they should abolish gestation crates immediately, because the public abhors them. I told them that 80% of the public would display such an attitude. I then challenged them to poll consumers. They did and told me that I was wrong. Their polling indicated not 80%, but 78%! They went on to tell me that they would abolish gestation crates in their facilities by 2018 and have scrupulously kept their word. Gratifyingly, they also asked me to speak to the *Wall Street Journal* to explain the change in policy.

Western society has always had a societal ethic for animal treatment, both in terms of what is prohibited and in terms of what is encouraged. The prohibitive ethic forbade deliberate, sadistic, purposeless infliction of pain and suffering on animals and outrageous neglect such as not feeding and watering. That ethic is encoded in the anti-cruelty laws of every civilized country, both for the sake of animals and because of the empirically confirmed insight that numerous psychopaths begin with abusing animals and ‘graduate’ to people (Ascione *et al.*, 1999). The ethic of encouragement was *good husbandry*, which formed the basis for animal agriculture historically. Producers did everything they could to place animals in the optimal environment for which they had evolved, and then provide food during famine, water during drought, protection from predation, whatever medical attention was available. This ethic was based in the strongest of all human motivations – self-interest. If one failed to provide good husbandry, the animals did not produce. This ethic underlies the 23rd Psalm.

End of Husbandry

By the mid-20th century, these venerable ethical principles for animal treatment were no longer sufficient. Whereas traditional animal agriculture involved, as it were, putting square pegs in square holes, round pegs in round holes and creating as little friction as possible, ever-increasing industrialization allowed for putting animals into environments

not congenial to them, by using what I call ‘technological sanders’, that allowed us to force square pegs into round holes. Productivity was unaffected, but animal welfare was severely compromised (Rollin, 2008).

This was not a result of cruelty, but rather an attempt to improve productivity and efficiency, with erosion of animal welfare an unfortunate side effect. Similarly, the mid-20th century rise of large amounts of research and safety and efficacy testing on animals caused a great deal of suffering, although no rational person would call it deliberate sadistic cruelty. Thus, a new animal ethic was demanded by society to cover the infliction of pain, suffering, deprivation and frustration of animal nature that resulted from these new uses.

New ethics do not come from nowhere, nor are they created *ex nihilo*. As Plato pointed out, new ethical ideas have to be rooted in established ethics. In Plato’s language, if one is attempting to change the ethics of an individual or a population, one cannot *teach*, one must *remind*. In other words, one must show the person or society that the ethic you are pressing is not new, but rather, implicitly or explicitly, contained in or a consequence of ethical principles they already hold and believe.

To put the point another way: changing a person’s ethical beliefs is very much like physical combat. You can pit your force against that of your opponent, as occurs with football lineman or in sumo competition. Alternatively, you can use your opponent’s force against them, as occurs in judo. In American history, Prohibition represented an attempt on the part of a minority to move the majority away from drinking. Inevitably, it failed and had many pernicious consequences, including actually increasing the amount of drinking in society.

Contrast this with Martin Luther King’s approach to civil rights and Lyndon Johnson’s civil rights legislation. As himself a Southerner, Johnson realized that even Southerners would acquiesce to the following two propositions, fundamental to American ethics: all humans should be treated equally; and black people were human – they just had never bothered to draw the relevant conclusion.

If Johnson had been wrong about this point, if ‘writing this large’ in the law had not ‘reminded’ people, civil rights would have been as ineffective as Prohibition. (For some readers with teenagers at home, they realize that while moral judo may sometimes work, force never does.)

At the same time, recall that Western society has gone through almost 50 years of extending its moral categories for humans to people who were morally ignored or invisible – women, minorities, the handicapped, children, citizens of the third world. (As late as the mid-1970s, the National Institutes of Health (NIH) had different and weaker moral standards for the use of Third World research subjects in federally funded research.) So a plausible and obvious move is for society to continue in its tendency and attempt to extend the moral machinery it has developed for dealing with people, appropriately modified, to animals.

In the US Constitution, specifically in the Bill of Rights, fundamental features of human nature are protected against infringement for the sake of the general welfare. These of course include freedom of speech, freedom of movement, holding on to one's property, not being tortured, freedom of expression, freedom of religion. Animals also possess fundamental natures determined by their biology – what Aristotle called their *Telos*. Being allowed to express and satisfy the interests dictated by their nature is as important to animals as avoiding pain. This is evidenced eloquently by certain animals chewing their legs off to escape from steel-jawed traps, showing that freedom is more important to them than pain.

Under traditional, husbandry-based agriculture, animal nature was respected, with such respect sanctioned by producer self-interest. Under industrial agriculture, this is no longer the case. It is clear that society and the social ethic see the actualization of animal *Telos* as fundamental to animals enjoying a positive quality of life. If respect for their natures is no longer presuppositional to animal use, society wishes to see it embodied in legislation – hence the articulation of the 2100 pieces of legislation pertaining to animal welfare promulgated across the USA in 2004. Hence too the evidence from Gallup polls. A Gallup poll conducted in 2003 showed that 75% of the public wanted legislated guarantees of farm animal welfare. By 2012, it had risen to 90% (Gallup 2003, 2012). Hence too the

relentless consumer thrust to eliminate gestation crates, battery cages, veal crates and all other high-confinement systems violative of animal nature. The same ethic prevails across all animal use. When I was a young man, zoos were in essence impoverished prisons for animals. Today those zoos would no longer survive.

The lesson for animal agriculture is plain. Society is very unlikely to abandon animal products. But it is clear that respect for the animals' needs and natures as determined by their *Telos* is presuppositional to societal comfort with animal production, as such respect determines animal quality of life. I would thus strongly advise the agricultural community to clean up its own house with respect to how animals are produced. Cows on pasture, chickens pecking freely, pigs allowed to roam on pasture with other pigs are ancient and iconic images with which all of us have been brought up. The issue is one of fairness and common decency, as well as self-protection. There is no reason to believe that animals have a concept of death or loss of life. But there is ample evidence that they worry how they live.

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18d

Animal Protectionist Viewpoint: Inhumane Slaughter Should be a Crime

ANDY LAMEY

Department of Philosophy, University of California, San Diego, USA

Recent decades have seen a shift in how society views the moral status of farmed animals. Up until the 1950s, American law permitted slaughterhouse workers to stun cows and pigs with multiple blows of a sledgehammer and to shackle and hoist them while still conscious. Today approximately half of the slaughter facilities in the USA use Temple Grandin's system of humane slaughter. Grandin's audit-based approach seeks to catalogue and minimize the frequency with which workers use cattle prods, require more than one shot of a stun gun to render animals insensitive, and other practices that were once considered perfectly acceptable (Lamey, 2019a). The increased use of Grandin's system has at key points been due to animal protection advocates applying pressure to the fast food industry (Singer, 1999: 166–176), but its popularity is not due to such advocacy alone. National opinion surveys indicate widespread support for regulations designed to reduce the suffering of farmed animals (ASPCA, 2019).

Rather than a passing fad, heightened concern with the well-being of farm animals is here to stay. Yet the institutionalization of this concern has not gone far enough. Use of systems such as Grandin's is currently voluntary when it should be mandatory. If we are serious about the welfare of farmed animals, we will make it a crime to kill them without making their death as merciful as possible.

Animals on American farms currently have few legal protections. In principle, federal law requires that they be quickly rendered unconscious before being killed, and that when they are transported across state lines for slaughter they be unloaded every 28 h to receive food and rest. In practice, both regulations have only the faintest impact. The

slaughter law excludes chickens, which constitute over 98% of land animals killed for food, as well as kosher and halal slaughter. The transportation regulations are punishable by a maximum fine of \$500 and in any event are rarely enforced, a fact that also holds true for the few state-level laws concerned with the welfare of farmed animals. Most states expressly exclude farmed animals from their anti-cruelty statutes.

Advocates for the welfare of farmed animals should support legislation requiring every slaughter facility to use Grandin's system. The fact that humane slaughter is already employed at many facilities, including those that kill chickens, shows that the industry can accommodate itself to humane slaughter in a systematic way. A wide range of businesses, from bars to contractors to dentists, have to meet licensing requirements as a condition of doing business. When it comes to the business of slaughtering, a basic cost of doing business should be a binding commitment to making the process as painless as possible.

The main reason for doing so is ethical. We take it for granted that our moral concern with our fellow human beings should be backed up with the force of law. We make it a crime to needlessly abuse members of our own species, including some with cognitive abilities less advanced than those of pigs and other 'livestock'. Although increased concern with the well-being of farmed animals is now widely affirmed, the rhetoric is not adequately joined with legal force. Taking the interests of animals seriously requires closing the gap between what we say they deserve and the painful outcomes that are all too likely to occur in slaughter facilities that do not allow welfare auditing.

I have argued elsewhere that animals have an interest not only in avoiding suffering but also in not being killed (Lamey, 2019b). Given this, it may seem incoherent to propose banning the inhumane elements of slaughter but not slaughter itself. As far as sheer morality is concerned, this criticism is sound. Killing animals for food when plant-based alternatives are widely available is morally indefensible. The law, however, must take into account factors beyond morality, including whether a legal command is likely to be obeyed. The widespread popularity of meat eating suggests that the public is unlikely to accept a ban on killing animals for food any time soon. A measure enforcing the new consensus on animal suffering, but which stops short of banning killing, is a compromise justified by crude political considerations regarding what the meat-eating majority, rightly or wrongly, is willing to abide by. Precisely because it would stop short of full justice for animals, such a law would have a greater chance of being enforced. At the same time it would do nothing to prevent continued advocacy regarding the moral wrong of killing animals for food.

A second possible objection is that such a reform is unlikely to happen, because lawmakers have historically shown little interest in the well-being of farmed animals (often, it is said, because agricultural agencies have been ‘captured’ by the industry they purportedly regulate). But introducing a bill in a legislature is not the only way to bring the law to bear on slaughterhouses. In recent years California, Florida, Colorado and other states have introduced animal welfare reforms through ballot initiatives. Where lawmakers have been reluctant to act, the

public has repeatedly endorsed measures to limit the cruelty of industrial agriculture. Initiatives obliging slaughter facilities to commit to humane slaughter are no more likely to fail than previous initiatives that outlawed sow gestation crates or required layer hens to live cage-free.

As with any legal change, banning inhumane slaughter would require answering many questions of detail, such as whether kosher and halal slaughter facilities should continue to be allowed to kill without stunning. As it stands, however, the discussion around farmed animal welfare is often framed as a matter of voluntary ethical concern. If we are serious about the needs of animals, we will recognize that their interest in avoiding suffering can no longer be viewed as an optional matter that slaughter facilities can accept or reject at their discretion. We will instead recognize that their well-being is so important that inadequate commitment to protecting it should be a crime.

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Animal Welfare Viewpoint: My Thoughts on Use of Animals for Food

TEMPLE GRANDIN

Department of Animal Science, Colorado State University, USA

Animal Welfare Perspective

I get asked all the time. How can you care about animals and be involved in slaughtering them? When my career started in the early 1970s, the cattle in the feedlots had a good life. In the dry Arizona climate, feedlot pens remained dry and the cattle had plenty of water and shade. Cattle handling was terrible, but I viewed it as a solvable problem. There were a few feedlot managers and ranchers who handled cattle quietly. I remember one ranch in particular. It was Singing Valley Ranch run by Bill and Penny Porter. Their beautiful cattle had a wonderful life. It became obvious that improving cattle handling was possible. The local Swift plant in Tolleson, Arizona was brand new when I started visiting it early in my career. Stunning was done well and the stunner was carefully maintained.

Management of large US slaughter plants in the 1970s was often better compared with the 1980s and 1990s. When the US industry suddenly expanded, they went through a sloppy phase where stunners were seldom repaired and handling was often brutal. If I had entered the industry in the 1980s or had been exposed to muddy disgusting feedlots early in my career, my career might have gone down a different path. The problems observed early in my career were viewed as fixable.

Welfare Auditing by Major Customers

In 1999, I was hired by McDonalds and Wendy's International to implement animal welfare auditing of the large abattoirs where they bought beef and pork. The scoring system I developed is described in Grandin (1998, 2005) and in Chapter 12.

The effectiveness of this programme is clearly illustrated in Bob Langert's book *The Battle to Do Good* (Langert, 2019). Bob Langert was the corporate manager at McDonalds who hired me. In my work with several large meat buyers, I saw animal welfare change from an abstract issue to something real. I took top managers on their first tours of farms and slaughterhouses. When they saw something bad, it motivated them to implement changes. It was like the TV show 'Undercover Boss'. They were sometimes shocked at what they saw.

During that year, I saw more positive change than I had seen in my previous 25 years. The good news was that animal welfare could be greatly improved without expensive remodeling and purchase of major equipment. Simple improvements such as stunner maintenance, non-slip flooring, changing lighting and better employee supervision brought all but three abattoirs out of 75 up to a decent welfare standard. More tips on how to improve animal handling are in Chapter 6. At three plants, a new general manager greatly improved animal welfare.

Lamey (2019) criticized the scoring system described in this book because it allows 5% of the cattle to have a missed stun. This is where the practical world collides with ideals. For any process, it is impossible to be perfect. The conditions were much worse before the audits started. A numerical cut-off provides clear guidelines to assist a buyer when they have to remove a poor slaughter plant from their approved supplier list. Industry guidelines are clear on acts of abuse that have a zero tolerance. Breaking tails or dragging fully conscious animals is *never* acceptable. Employees need to be trained and given a list of acts of abuse.

An employee who commits an act of abuse should be fired from their job.

The Animals Must Have a Life Worth Living

The cattle that I worked with in the 1970s had a life worth living. Unfortunately, a relatively new problem started occurring with lameness, heat stress and feedlot cattle that die when they are almost at slaughter weight. The problem crept up slowly. It was caused by a combination of factors such as: (i) heavier at a younger age; (ii) genetic selection for heavier carcasses; (iii) excessive grain in the ration; and (iv) feeding beta agonists. This is discussed in Grandin and Whiting (2018) and in this book. Some of these animals are stiff and sore and their lives are miserable. This problem does not occur in all feedlot cattle. There are 10–20% of feeders who push the animal's biology too hard and compromise welfare. It happens when animal weight gain is maximized. Young managers starting a career in the feedlot industry are often not aware that feedlot cattle 20 years ago were seldom lame. This is why I call this 'bad becoming normal'. The industry did not like it when I spoke out on this issue. This resulted in a backlash against me by some people in the beef industry. This was a very difficult time for me.

Improving Slaughter was Easy

Compared with problems on the farm, improving slaughterhouses was easy. Today the biggest welfare issues I have observed in modern slaughter plants are problems caused by poor conditions on the farm. This is why this book has extensive information on monitoring on-farm welfare issues at the abattoir (see Chapters 4 and 16). When I stand at the truck unloading ramp, I am often not happy with what I see. Fortunately, a few good things have started happening. Recently one really progressive large slaughter plant stopped buying cattle that were lame or had high levels of liver abscesses.

Ethical Issues

The contribution by Andy Lamey discusses my views on the ethics of eating meat. There are more extensive essays on my views in Grandin (1995) and Grandin and Johnson (2010). In many of my writings, I have stated that an animal being killed by a predator has a worse death than a cow or pig in a modern slaughterhouse. Lamey stated that animal death in the wild is required to sustain ecosystems (Lamey, 2019). People killing animals for food may harm ecosystems if it is done in an irresponsible way. This brings up a fundamental issue about moral values concerning the natural world. One viewpoint is: if it is natural, then it is acceptable. This is not an abstract issue for me. I have been on a ranch and seen a calf that was partially skinned alive by coyotes. The rancher shot it to put it out of its misery. These are complicated issues. The purpose of these short sub-chapters in Chapter 18 are to enable the reader to see different perspectives. This can encourage people to have constructive dialogue instead of getting into hyper-polarized arguments.

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